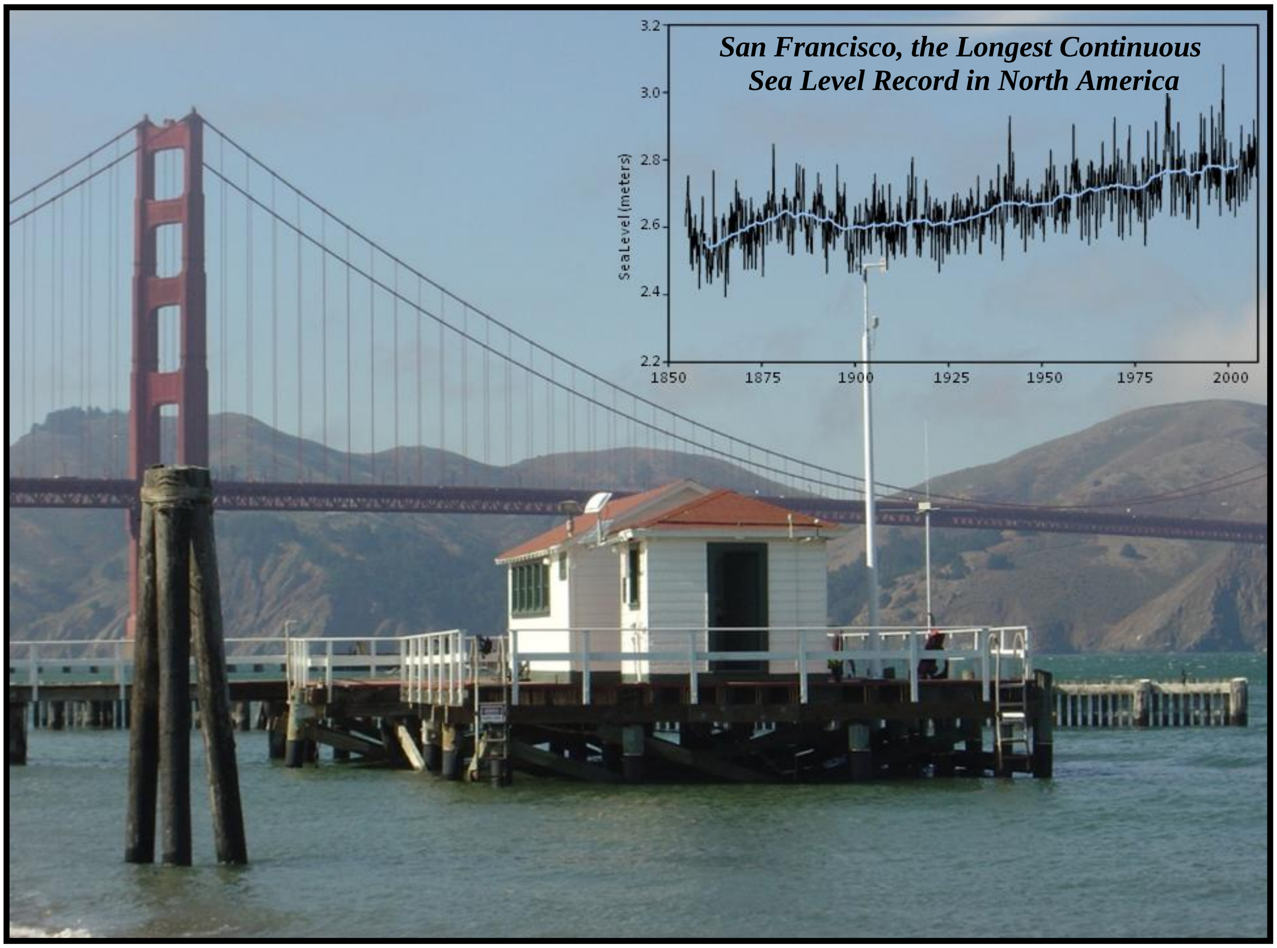
Technical Report NOS CO-OPS 053

SEA LEVEL VARIATIONS OF THE UNITED STATES 1854-2006



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U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) provides the National infrastructure, science, and technical expertise to collect and distribute observations and predictions of water levels and currents to ensure safe, efficient and environmentally sound maritime commerce. The Center provides the set of water level and tidal current products required to support NOS' Strategic Plan mission requirements, and to assist in providing operational oceanographic data/products required by NOAA's other Strategic Plan themes. For example, CO-OPS provides data and products required by the National Weather Service to meet its flood and tsunami warning responsibilities. The Center manages the National Water Level Observation Network (NWLON), a national network of Physical Oceanographic Real-Time Systems (PORTS) in major U. S. harbors, and the National Current Observation Program consisting of current surveys in near shore and coastal areas utilizing bottom mounted platforms, subsurface buoys, horizontal sensors and quick response real time buoys. The Center: establishes standards for the collection and processing of water level and current data; collects and documents user requirements which serve as the foundation for all resulting program activities; designs new and/or improved oceanographic observing systems; designs software to improve CO-OPS' data processing capabilities; maintains and operates oceanographic observing systems; performs operational data analysis/quality control; and produces/disseminates oceanographic products.

Cover photo of the San Francisco Sea Level Station maintained by NOAA's Center for Operational Oceanographic Products and Services.

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Chris Zervas

December 2009

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NOTICE

FOREWARD

The United States National Water Level Network (NWLON) was established in the 19th Century to ensure the Nation's nautical charts, shoreline maps, and elevations relative to homes, levees, and other coastal infrastructure were accurately referenced to sea level. In support of this mission, NOAA's Center for Operational Oceanographic Products and Services and its predecessors have determined sea level for the United States since the mid 19th Century. While climate change was not a concern during the mid-1800s, the accurate determination of sea level was critical for navigation and marine boundary determination. To meet these important requirements, technology, procedures, and processes were developed to the highest scientific and engineering standards.

At the turn of the 20th Century it was realized that there was a need to account for a rise in sea level and the first National Tidal Datum Epoch was established. Today this Epoch is updated every 20 to 25 years. The Supreme Court recognized these standards and procedures in the landmark 1936 case of *Borax, Ltd v. City of Los Angeles* when legally defining sea level. Due to those initial efforts and the continued dedication of those charged with the responsibility for monitoring sea level for the United States, we can accurately determine relative (local) mean sea level along the Nation's coastline today. These observations also play an important role in monitoring change in global sea level.

As we monitor change in sea level into the 21st Century, the statement made by Alexander Dallas Bache, the Second Superintendent of the Coast Survey, is as relevant today as when it was stated more than 150 years ago, "It seems a very simple task to make correct tidal observations; but, in all my experience, I have found no observations which require such constant care and attention" (1854).

Michael Szabados
Director, Center for Operational Oceanographic Products and Services

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

CO-OPS	Center for Operational Oceanographic Products and Services
ENSO	El Niño/Southern Oscillation
MSL	Mean Sea Level
MTDE	Modified Tidal Datum Epoch
NOAA	National Oceanographic and Atmospheric Administration
NOS	National Ocean Service
NTDE	National Tidal Datum Epoch
NWLON	National Water Level Observation Network
TCOON	Texas Coastal Ocean Observation Network

EXECUTIVE SUMMARY

Monthly mean sea level (MSL) data for 128 long-term National Water Level Observation Network (NWLON) stations of the Center for Operational Oceanographic Products and Services (CO-OPS) are analyzed in this report. All available data up to the end of 2006 are used to determine linear trends, average seasonal cycles, and interannual variability including estimated errors. The stations are located on the U.S. Atlantic and Pacific coasts, the Gulf of Mexico, Hawaii, Alaska, and on islands in the Atlantic and Pacific Oceans.

The linear trends obtained are *relative* MSL trends which are a combination of the absolute global rate of sea level rise (1.7 +/- 0.5 mm/yr in the 20th century) and the rate of any local vertical land motion. The variation in vertical land motion, ranging from rapid subsidence in Louisiana and eastern Texas to rapid uplift in Alaska, is primarily responsible for the regional differences in MSL trends and for the differing rates within regions. Separate pre- and post-seismic trends were calculated for some stations in Alaska and Guam with apparent seismic offsets in 1957, 1964, or 1993.

Time series plots of the monthly MSL data with the seasonal cycle removed are located in the appendices along with the 12-month average seasonal cycle for each station. The average seasonal cycles are used to derive the two tidal constituents that represent the regular seasonal variation which are then compared to the tidal constituents routinely used by CO-OPS to make the official tide predictions. The residual time series after the seasonal cycles and trends are removed represent the regional oceanic interannual variability, which is highly correlated from station to station. Using a 5-month running average of the residual, thresholds of +0.1 and -0.1 meters are defined for positive and negative anomalies.

Each calculated linear trend has an associated 95% confidence interval that is primarily dependent on the year range of data for each station. A derived inverse power relationship indicates that 50-60 years of data are required to obtain a trend with a 95% confidence interval of +/- 0.5 mm/yr. This dependence on record length is caused by the interannual variability in the observations. A series of 50-year segments were used to obtain linear MSL trends for the stations with over 80 years of data. None of the stations showed consistently increasing or decreasing 50-year MSL trends, although there was statistically significant multidecadal variability on the U.S. east coast with higher rates in the 1930s, 1940s and 1950s and lower rates in the 1960s and 1970s.

The long-term MSL changes at NWLON stations require that CO-OPS periodically introduce a new 19-year National Tidal Datum Epoch (NTDE) every 20-25 years to keep the datums up-to-date. In specific areas with rapid rates of vertical land motion, CO-OPS has adopted special 5-year Modified Tidal Datum Epochs (MTDEs) to prevent the datum elevations from becoming obsolete before the next nationwide update. In this report, it is recommended that CO-OPS

implement a rule that when a 5-year averaged MSL differs by at least 0.1 meters from a previously-established datum, a new 5-year MTDE should be adopted for that station.

INTRODUCTION

The initial motivation for measuring water level variations over time was to study the tide. Although the tide-producing forces were understood in general, each coastal location responds to the forcing differently, requiring a series of hourly observations to derive its unique tidal constituents. A month to a year of observations was sufficient to resolve the tidal constituents needed to make accurate tide predictions for navigational purposes; however, scientists began to see other phenomena in the records, including storm surges, seiches, tsunamis, and interannual variations in the seasonal cycle. Therefore, observations were continued at some locations even though the tidal constituents were already well known. Eventually, after several decades of measurements had accumulated, long-term trends in the mean level of the oceans began to emerge.

Because the water level measurements were tied to a continuously-maintained local station datum on land (Gill and Schultz 2001), the observed trends were relative; an observed trend could be due to vertical motion of the land or the ocean or both. Gradually, it became apparent that most stations around the world showed rising sea levels with only regions of active tectonic activity or glacial isostatic rebound recording falling sea levels. This led to the conclusion that the absolute level of the global oceans had been slowly rising since the mid-1800s. The vital importance of continuing to record long-term water level series for all coastal regions became clear.

In the United States, the national water level network has been operated and maintained by the Center for Operational Oceanographic Products and Services (CO-OPS) of NOAA's National Ocean Service (NOS) and its predecessor agencies for over 150 years. The National Water Level Observation Network (NWLON) has expanded over the years to presently consist of 205 permanent stations. The stations are located in all 24 coastal states and the District of Columbia, on the Great Lakes, and on U.S. island territories and possessions in the Atlantic and Pacific Oceans. Bermuda and Kwajalein are the only CO-OPS stations presently operating in foreign countries.

Sea level trends and variations at NWLON stations were previously published by NOS using data from 44 stations (Hicks and Shofnos 1965), 50 stations (Hicks and Crosby 1974), 67 stations (Hicks, Debaugh and Hickman 1983), 78 stations (Lyles, Hickman and Debaugh 1988), and 117 stations (Zervas 2001). The Permanent Service for Mean Sea Level (PSMSL), the global data bank for sea level data from tide stations, maintains a listing of sea level trends at hundreds of stations worldwide (http://www.pol.ac.uk/psmsl/datainfo/rlr.trends). The CO-OPS website contains a section (http://tidesandcurrents.noaa.gov/sltrends/) that provides sea level analyses at all the long-term NWLON stations and at a selected set of non-U.S. stations that were analyzed using data obtained from PSMSL.

This report is an update of NOAA Technical Report NOS CO-OPS 36 (Zervas 2001) including seven additional years of data. The variations computed are the linear trends, the average seasonal cycles, and the interannual variations. Stations with a 30-year data range were used because, in the previous report, the trends that were calculated with only a 25-year data range had wide error bars and, in some cases, differed noticeably from longer-term stations in the vicinity. The report now includes analyses for 128 NWLON stations.

The data to be analyzed are monthly MSLs, which are the arithmetic average of all the hourly data for each complete calendar month. The data are relative to the mean sea level datum of each station as established by CO-OPS for the most recent National Tidal Datum Epoch (NTDE) of 1983-2001. An NTDE consists of 19 years to take into account variations in tidal range due to the 18.6-year cycle of the moon's angle of obliquity. Previous NTDEs were 1924-1942, 1941-1959, and 1960-1978. CO-OPS has a policy of updating the NTDE every 20-25 years to account for the effect of long-term sea level change. The datums for the most recent NTDE went into effect in 2003 and will likely remain in effect until sometime after 2020.

For a few stations in Louisiana, Texas, and Alaska, with rapid rates of relative sea level change, CO-OPS has introduced revised datums based on 5 years of MSL data. Some of these 5-year Modified Tidal Datum Epochs (MTDEs) were 1990-1994, 1994-1998, 1997-2001, and 2002-2006. These datums are considered for revision every 5 years for each station, based on how much sea level has changed at a station since the last update.

Because a relative sea level trend measured by a water level station includes land motion as well as absolute sea level changes, there are major differences in the trend from location to location. At some coastal locations sea levels are rising while at others sea levels are falling. Although there may be some small multidecadal regional differences in the absolute sea level trends, most of the variation in the relative sea level trends is due to differential vertical land motion caused by glacial isostatic adjustment (GIA), tectonic movement (seismic and interseismic), sedimentary basin subsidence, soil compaction, and fluid withdrawal. Except for tectonic activity and fluid withdrawal, these movements are expected to be essentially linear over any period of instrumentally-recorded water level measurements.

GIA is the delayed response of the lithosphere to the melting of the North American and Fennoscandian ice sheets including both the rise of the previously-glaciated regions and the fall of the peripheral compensating bulge (Sella et al. 2007). A smaller-scale example of GIA, with extremely rapid uplift, has been occurring in southeast Alaska following the collapse of the Glacier Bay Icefield beginning in the late 1700s (Larsen et al. 2004, Larsen et al. 2005).

Tectonic activity includes both instantaneous seismic displacement, as well as long-term interseismic deformation which can become nonlinear immediately before or after the greatest magnitude earthquakes. Therefore, offsets and differing pre- and post-seismic rates may be possible at NWLON stations near plate boundaries in California, Oregon, Washington, and

Alaska (Cohen and Freymueller 2001, Larsen et al. 2003, Burgette, Weldon and Schmidt 2009). Subsidence, soil compaction, and fluid withdrawal can all have varying effects on relative sea level trends in coastal Louisiana and Texas (Dokka, Sella and Dixon 2006, Ivins, Dokka and Blom 2007).

Various methods have been employed over the years to account for vertical land motion in order to determine a global absolute sea level rate (e.g. Douglas (1991)). The lastest IPCC report gives a global sea level rise of 1.7 +/- 0.5 mm/yr for the 20th century (Solomon 2007). This value is in good agreement with most previous studies (Douglas 1997).

The 20th century rate of sea level rise could not have been sustained over the previous millennium without noticeable widespread consequences, which prompted a search for a detectable acceleration in global sea level records (Woodworth et al. 2009). Earlier research using data up to the 1980s found no statistically significant acceleration in the 20th century (Woodworth 1990, Douglas 1992); however, investigators have combined the global spatial coverage of the satellite altimetry record (only since 1993), with the temporal coverage of the long-term water level stations using an empirical orthogonal function analysis. When globally reconstructed time series are extended back into the 19th century (Church and White 2006), a small acceleration is detected. A recent study has extended the reconstruction back into the 18th century using a different analysis method (Jevrejeva et al. 2008).

Satellite altimetry indicates a global sea level trend of over 3 mm/yr since 1993 (Nerem, Leuliette and Cazenave 2006). The latest satellite altimetry trends can be found at http://ibis.grdl.noaa.gov/SAT/slr/. The recent global trend raises the question of whether there has been a recent acceleration over the 20th century rate or if the recent trend is part of a multidecadal global fluctuation in the longer-period rate of 1.7 mm/yr. Some studies have found that the present-day global rate may have been equaled or exceeded for short periods of time earlier in the 20th century (Jevrejeva et al. 2006, Holgate 2007).

Satellite altimetry has also revealed large regional differences in the absolute sea level trends since 1993 (Cazenave and Nerem 2004), with some regions such as the western Pacific showing extremely rapid rises contrasted with negative trends along much of the U.S. west coast and Alaska. These short-term trends are very different from the longer-term trends measured by water level stations in those areas indicating significant shorter-term regional variability. Using empirical orthogonal function analysis, Church et al. (2004) reconstructed the regional variation in sea level trends for the period 1950-2000 and found a completely different pattern of regional absolute sea level trends. Sea level trends near both U.S. Atlantic and Pacific NWLON stations were between 2 and 3 mm/yr, which is slightly above the global average trend. It has also been observed that the mean of near-coast sea level trends from satellite altimetry since 1993 has been greater than the global average trend (Holgate and Woodworth 2004); however, reconstructed sea level trends over the period 1950-2000 indicate that there have been periods when the near-coast trends have been both above and below the global ocean average trend (White, Church and Gregory 2005).

WATER LEVEL STATIONS

The historical CO-OPS database was used to compile monthly mean sea levels for a total of 128 NWLON stations that had a data range of at least 30 years. More historical data documented on paper forms were examined and, if the station datum could be verified, were used to extend some of the measurements further back in time, beyond the records in the electronic database. Twelve stations are analyzed in addition to those in the previous technical report (Zervas 2001). These new stations are: Reedy Point, DE; Ocean City, MD; Chesapeake City, MD; Oregon Inlet Marina, NC; Southport, NC; Daytona Beach Shores, FL; Redwood City, CA; Port Chicago, CA; North Spit, CA; Port Orford, OR; Garibaldi, OR; and Lime Tree Bay, VI.

Most of the stations have fairly complete records with only a few sporadic years of missing data. A few stations were not operational for longer periods; however, the range of time from the beginning to the end of the series is the most important factor in producing MSL trends with reasonable error bars that are consistent with nearby stations having more complete records.

The 128 NWLON water level stations analyzed in this report are listed in Appendix I which gives the station number, latitude, longitude, first year of data, last year of data, year range, station name, and state or territory. The locations of the stations are shown on the maps in Figures 1-7. The size of the marker indicates the length of each data set. The epicenters of the large magnitude earthquakes (magnitude > 7.5) listed in Table 1 are also shown. Three of these earthquakes in 1957, 1964, and 1993 resulted in discernable offsets and/or changes in trend at some of the nearest water level stations.

Table 1. Major Earthquakes near NWLON Stations

Date	State or Territory	Longitude	Latitude	Magnitude
04/18/1906	California	-122.480	37.670	7.7
03/09/1957	SW Alaska	-175.630	51.290	8.8
07/10/1958	SE Alaska	-136.520	58.340	8.3
03/28/1964	South Alaska	-147.730	61.040	9.2
07/30/1972	SE Alaska	-135.690	56.820	7.6
11/29/1975	Hawaii	-155.000	19.340	7.5
02/28/1979	South Alaska	-141.600	60.640	7.6
05/07/1986	SW Alaska	-174.750	51.330	8.0
11/30/1987	SE Alaska	-142.790	58.680	7.9
03/06/1988	SE Alaska	-143.030	56.950	7.7
08/08/1993	Guam	144.801	12.982	8.0
06/10/1996	SW Alaska	-177.630	51.560	7.9

Stations with a year range of at least 30 years were selected. With the 25-year criterion used in the previous technical report (Zervas 2001), the stations with the shortest length of data had trends that had wide error bars and sometimes differed noticeably from other nearby stations. Two stations used in the previous report, New Rochelle and Rincon Island, still do not have 30 years of data because they have been discontinued.

The previous trend at New Rochelle, NY was based on only 25 years of data from 1957 to 1981 and was substantially lower than the trend at the nearby long-term station at Willets Point, NY. A trend calculated using only 1957-1981 Willets Point data is also much lower than the long-term Willets Point trend. Since no new data were collected at New Rochelle in the intervening years, the station is not included in this report.

The previous trend at Rincon Island, CA was calculated with 29 years of data from 1962 to 1990. Even though it is 1 year less that the 30-year criterion, it has been included in this report; however, its trend is substantially higher than other nearby station trends. Because Rincon Island is a small artificial island built about 1 kilometer offshore for oil and gas production, its trend may not be representative of a larger area.

Some of the other stations analyzed are not presently in operation. These stations and their last year of data are: Johnston Atoll (2003); Chuuk (1995); Seavey Island (2001); Port Jefferson (1992); Colonial Beach (2003); Gloucester Point (2003); Portsmouth (1987); Daytona Beach Shores (1983); Miami Beach (1981); Eugene Island (1974); Newport Beach (1993); and Guantanamo Bay (1971).

Occasionally, various circumstances have required the relocation of a station. If the old and new stations are tied to some of the same bench marks, the old station's series can be continued at the new location. At the stations listed in Table 2, data from two or more locations were combined. Sometimes, the two stations were operated in tandem for a period to confirm the similarity of their tidal signals. In other cases, such as when a pier was destroyed in a storm, collecting a period of overlapping data was not possible. All of the stations that were combined were placed on a common datum on the basis of a direct leveling connection to common bench marks except for the Willets Point / Kings Point, NY series; however, these two stations were both in operation from November 1998 to December 2000 and had nearly identical hourly time series, so it was decided to combine them, making the assumption that there is no mean sea level difference between them.

CO-OPS stopped collecting data from Padre Island in 1994 and from Port Mansfield in 1997. The Texas Coastal Ocean Observation Network (TCOON) had installed a station very close to the NWLON Padre Island station in 1993. The two stations had some bench marks in common and were both operating in tandem for a year from May 1993 to April 1994. TCOON also reinstalled the Port Mansfield station in 1998 and has operated it since then. For these two stations, monthly mean sea levels from the TCOON website were downloaded (http://lighthouse.tamucc.edu/TCOON/HomePage), adjusted to the NWLON MSL datums, and appended to the NWLON data.

Table 2. Combined Stations

Station Number	Station Name	Data Periods
2695535	Bermuda Biological Station	1932-1937
	Bermuda Esso Pier	1939-1943
	Bermuda Biological Station	1944-1992
2695540	Bermuda Esso Pier	1988-2006
8419870	Seavey Island, Navy Yard	1926-1969
	Seavey Island, Back Channel	1969-1973
	Seavey Island, Berth 2	1973-2001
8443970	Boston, Commonwealth Pier #5	1921-1939
	Boston, Appraisers Wharf	1939-2006
8516990	Willets Point	1931-2000
8516945	Kings Point	1998-2006
8518750	Governors Island	1856-1878
	Fort Hamilton	1893-1933
	The Battery	1920-2006
8534720	Atlantic City, Million Dollar Pier	1911-1920
	Atlantic City, Steel Pier	1922-1985
	Ventnor City	1985-1991
	Atlantic City, Steel Pier	1991-2006
8545530	Philadelphia, Chestnut Street Pier	1900-1920
	Philadelphia, Pier 9 North	1922-1962
	Philadelphia, Pier 11 North	1962-1989
8545240	Philadelphia, USCG Station	1989-2006
8551910	Reedy Point	1956-1965
	Reedy Point Fishing Pier	1973-2006
8557380	Lewes, Fort Miles	1919-1939
	Lewes	1947-2006
8570280	Ocean City Fishing Pier	1975-1991
8570283	Ocean City Inlet	1997-2006
8571890	Cambridge, Yacht Basin	1943-1980
8571892	Cambridge, Marine Terminal	1980-2006
8575512	Annapolis, Naval Academy	1928-1970
	Annapolis, Naval Station	1970-1978
	Annapolis, Naval Academy	1978-2006
8656495	Morehead City	1953-1962
8656483	Beaufort	1964-2006
8661000	Myrtle Beach	1957-1977
8661070	Springmaid Pier	1977-2006
8720220	Mayport	1928-2000
8720218	Bar Pilots Dock	2001-2006

Table 2. Combined Stations		
Station Number	**Station Name**	**Data Periods**
8721020	Daytona Beach	1925-1950
8721120	Daytona Beach Shores	1966-1983
8724580	Key West, Curry's Wharf	1913-1926
	Key West, Naval Base	1926-2006
8761720	Grand Isle, Bayou Rigaud	1947-1980
8761724	Grand Isle, East Point	1980-2006
8770590	Sabine Pass	1958-1985
8770570	Sabine Pass North	1985-2006
8778490	Port Mansfield	1963-1997
TCOON-017	Port Mansfield	1998-2006
8779750	Padre Island	1958-1994
TCOON-051	South Padre Island	1993-2006
9410170	San Diego, Quarantine Station	1906-1926
	San Diego, Municipal Pier #1	1926-2006
9412110	Avila Beach	1945-1970
	Port San Luis	1971-2006
9414290	San Francisco, Fort Point	1854-1877
	Sausalito	1877-1897
	San Francisco, Presidio	1897-1927
	San Francisco, Presidio (Crissy Field)	1927-2006
9457292	Kodiak Harbor, Womens Bay	1949-1964
9457283	Kodiak, St. Pauls Harbor	1964-1984
9457292	Kodiak Harbor, Womens Bay	1984-2006
9462611	Dutch Harbor	1934-1955
9462620	Unalaska	1955-2006
9755371	San Juan, Naval Base	1962-1975
	San Juan, USCG Base	1977-2006

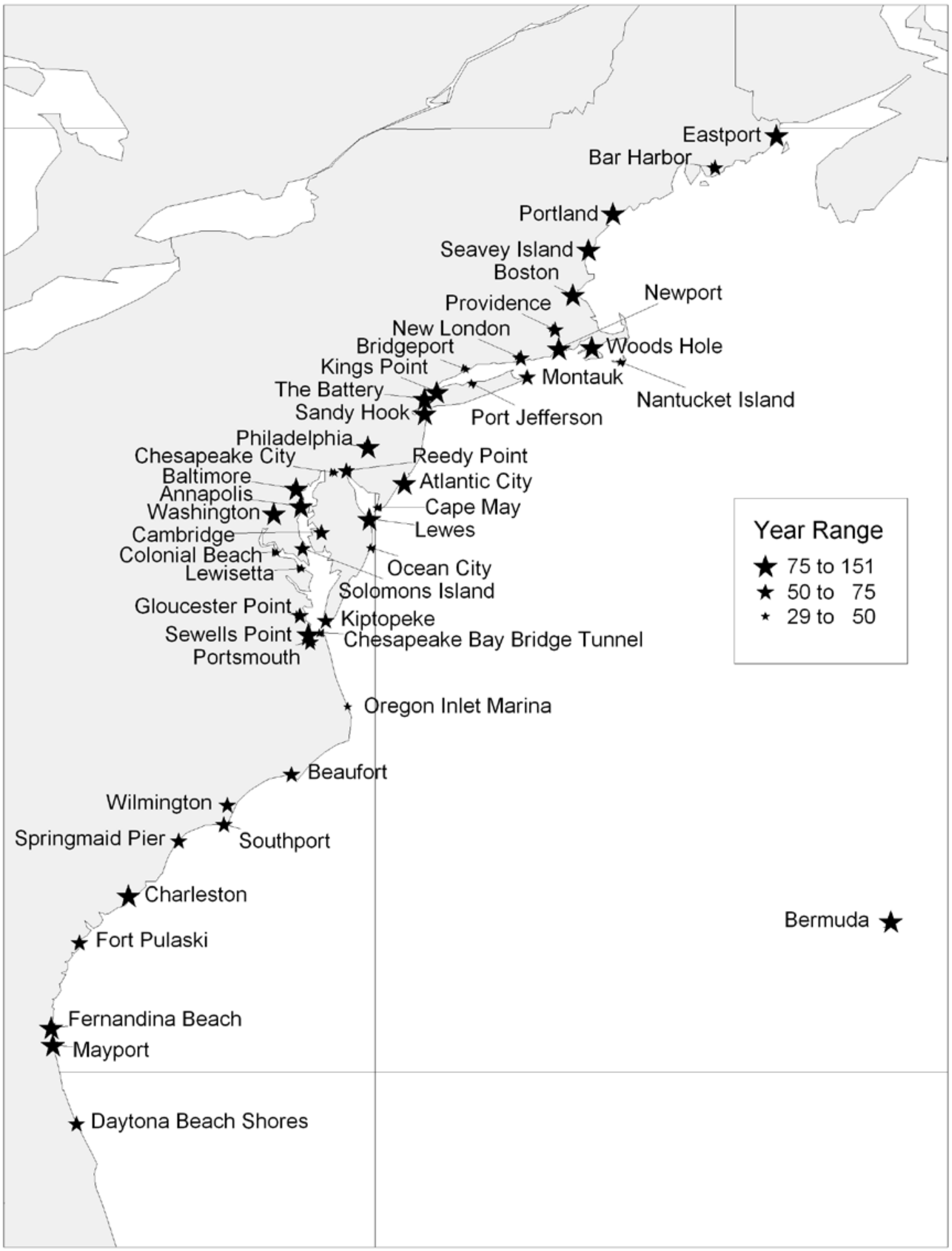


Figure 1. Long-term NWLON stations on the U.S. east coast and Bermuda

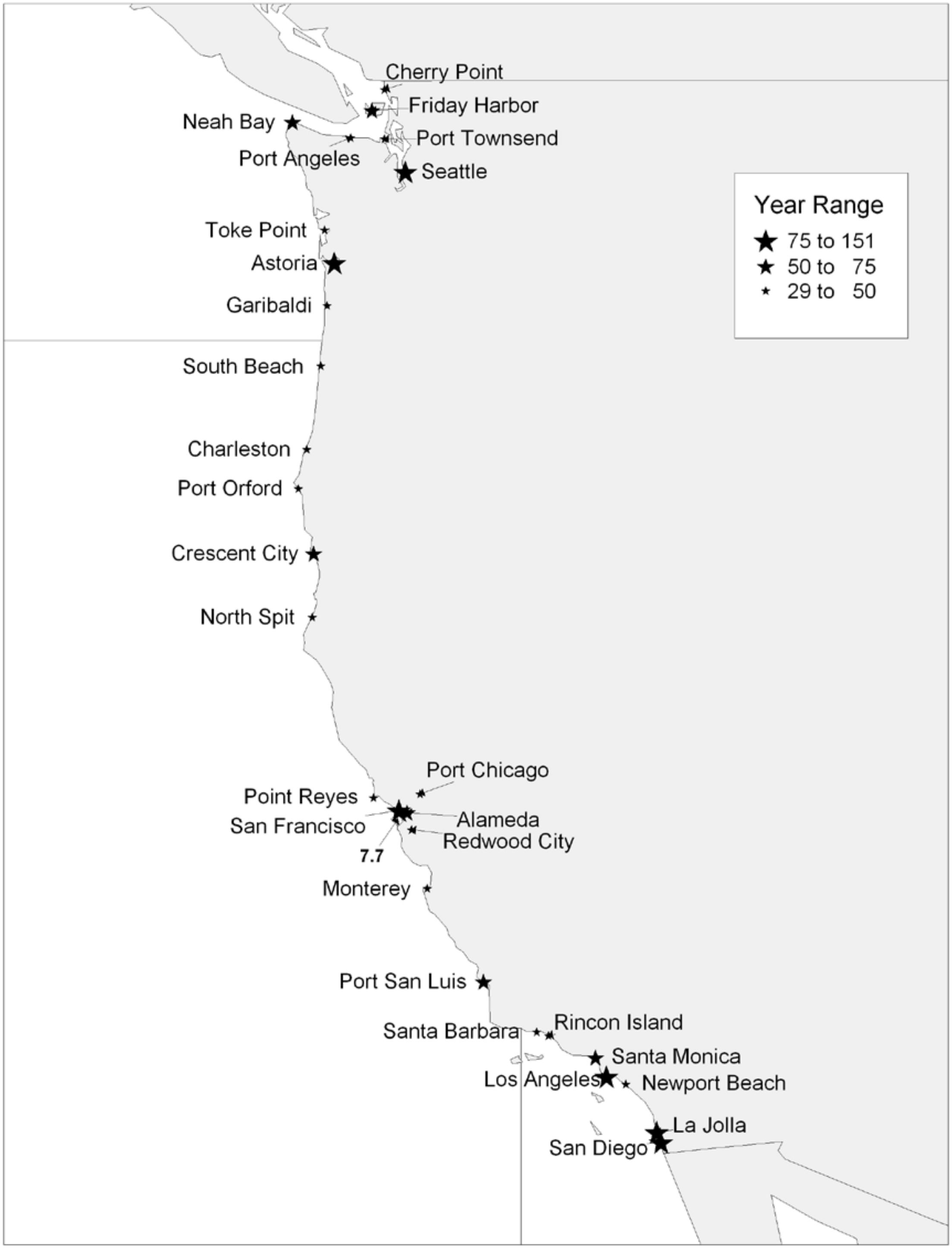


Figure 2. Long-term NWLON stations on the U.S. west coast with major earthquake indicated by its magnitude.

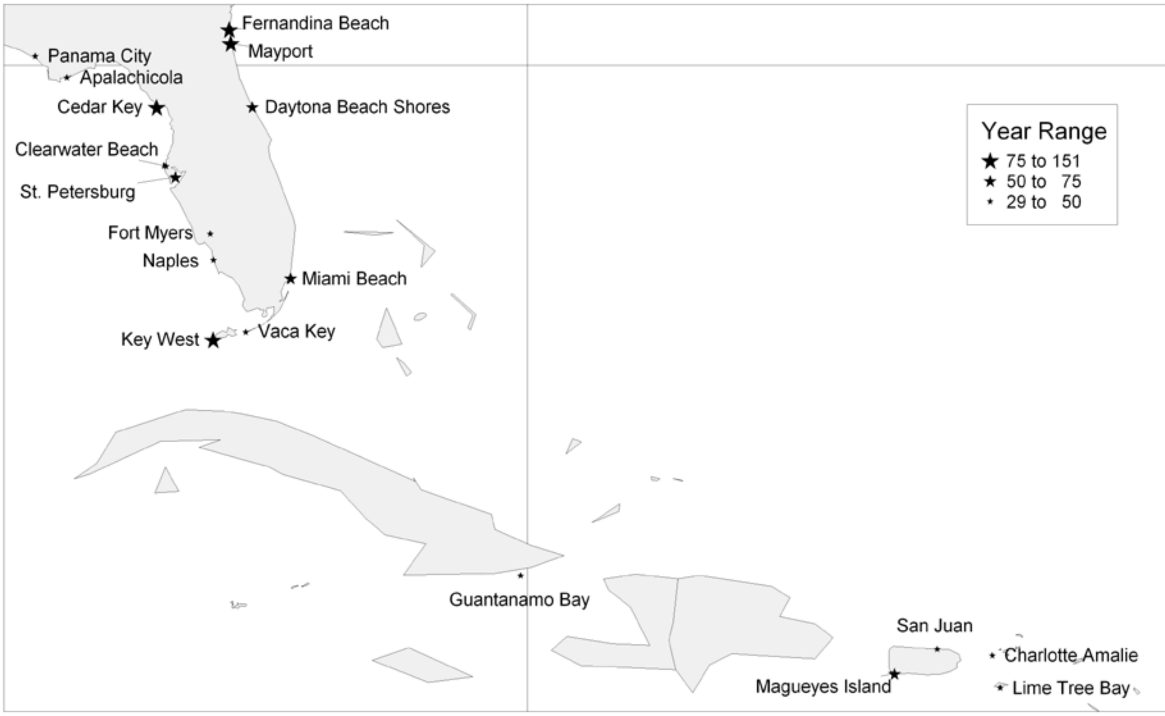


Figure 3. Long-term NWLON stations in the eastern Gulf of Mexico and Caribbean.

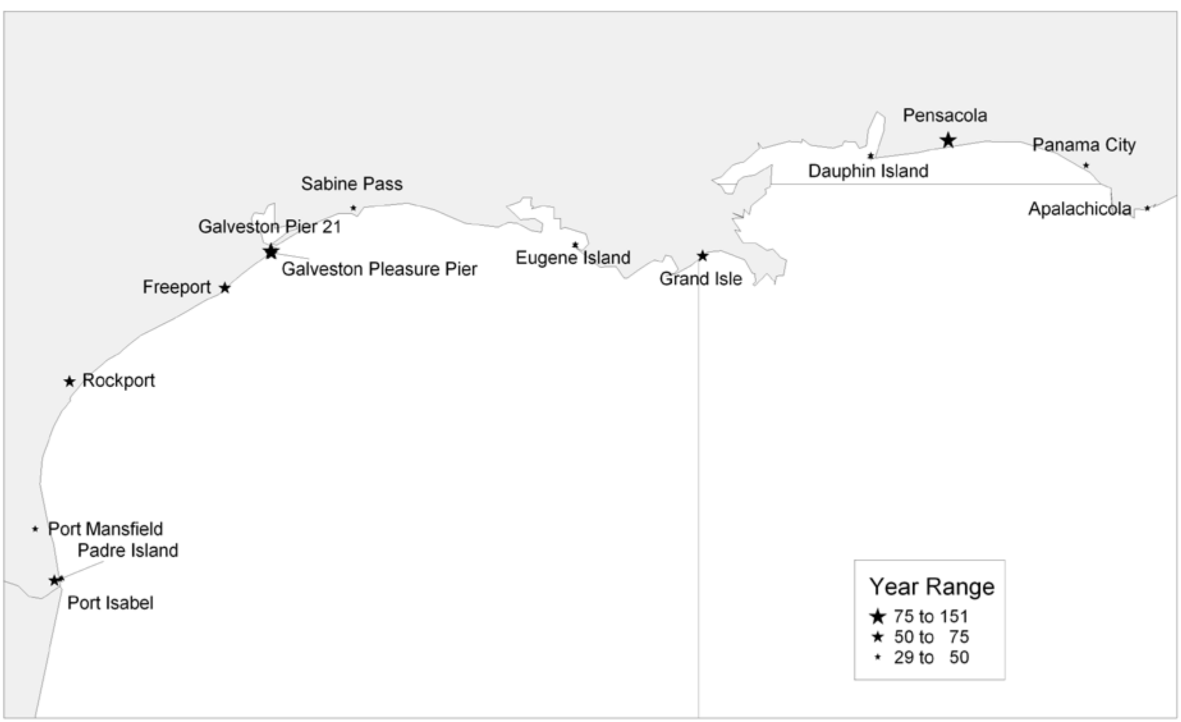


Figure 4. Long-term NWLON stations in the western Gulf of Mexico.

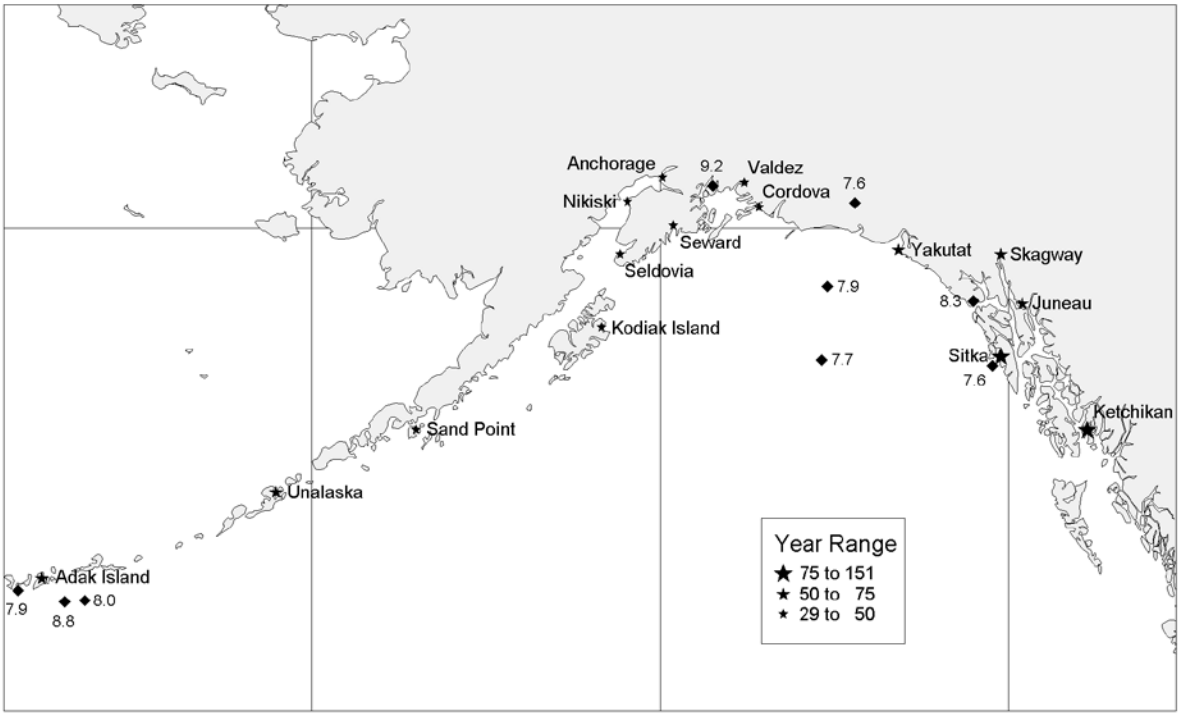


Figure 5. Long-term NWLON stations in Alaska with major earthquakes indicated by magnitude.

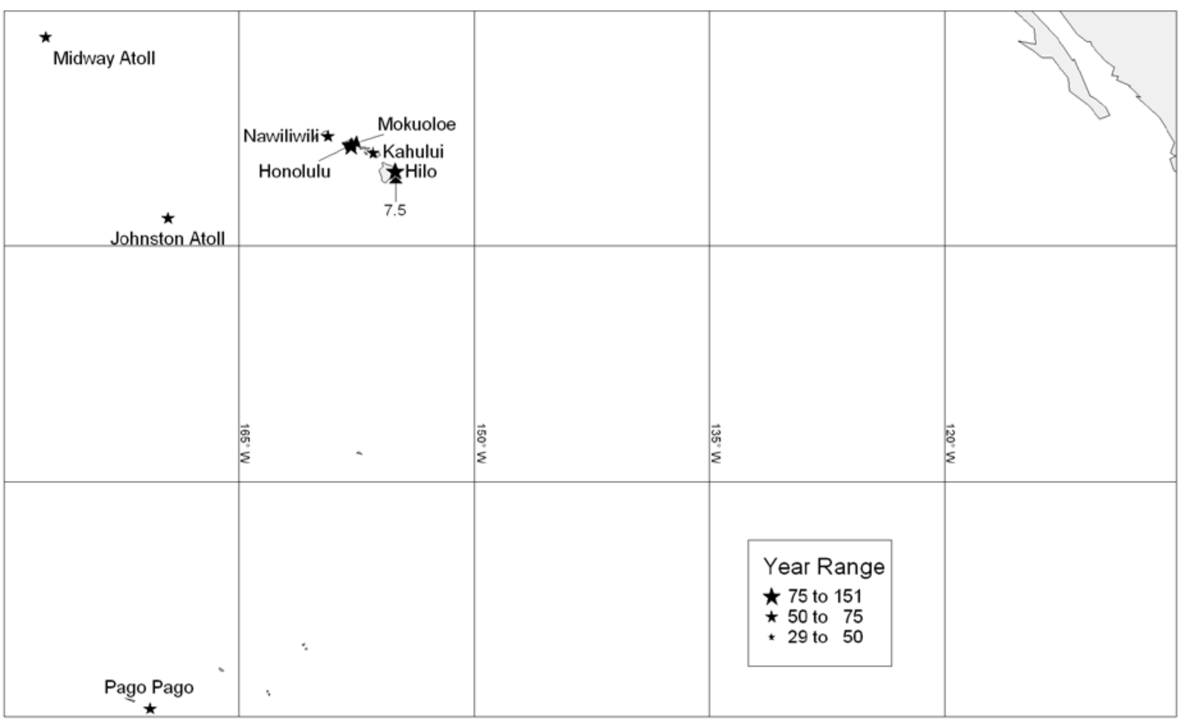


Figure 6. Long-term NWLON stations in the eastern Pacific with major earthquake indicated by its magnitude.

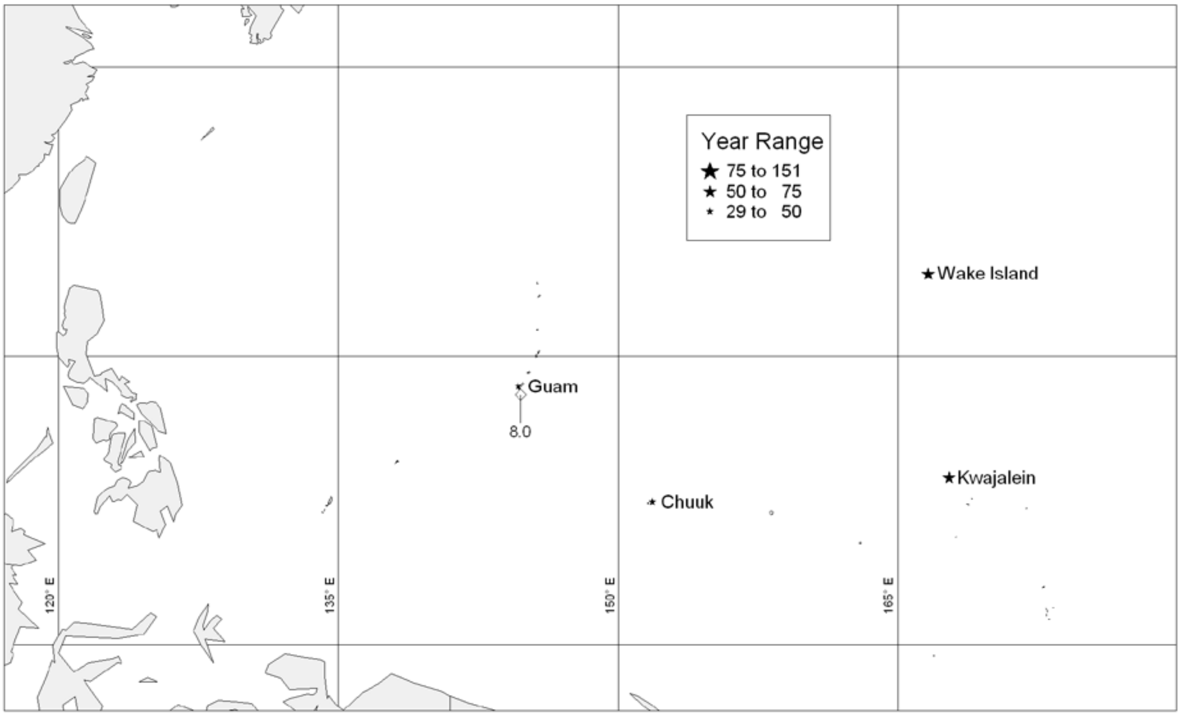


Figure 7. Long-term NWLON stations in the western Pacific with major earthquake indicated by its magnitude.

DERIVATION OF MEAN SEA LEVEL TRENDS

Mean sea level trends are often calculated by fitting a simple line to a series of annual mean sea levels, although more information can be obtained by working with monthly mean sea levels. Often stations have additional partial years of monthly data available that were not sufficient to compute an annual mean. The monthly data can also be used to obtain the average seasonal cycle represented as 12 mean values. The residual time series after the trend has been removed contains valuable information about the correlation of the interannual variability between stations, which is better defined by a monthly residual series than by an annual residual series. Trends derived from monthly MSL data also have smaller standard errors as was shown in Zervas (2001).

A least squares solution can be obtained for the slope b of a fitted linear trend and for the 12 monthly values m_j representing the average seasonal cycle as

$$y_i = bt_i + m_j + \varepsilon_i \tag{1}$$

where y_i are the monthly MSLs, t_i represents the time in fractional years and ε_i is the residual or error times series. The slope or trend b can be expressed as

$$b = [\ \sum (t_i - T)(y_i - Y)\ ]\ /\ [\ \sum (t_i - T)^2\ ] \tag{2}$$

where T is the mean t_i and Y is the mean y_i. The standard error of the trend s_b can be expressed as

$$s_b = [\ \sum (y_i - Y)^2 - b \sum (t_i - T)(y_i - Y)\ ]^{1/2}\ /\ [\ (n\text{-}2) \sum (t_i - T)^2\ ]^{1/2} \tag{3}$$

where n is the number of data points.

Least squares linear regression will give an accurate MSL trend b but it can substantially underestimate the standard error or uncertainty of that trend s_b. The reason is that, for sea level data, the residual time series ε_i is serially autocorrelated even after the average seasonal cycle is removed. Each month is partially correlated with the value of the previous month and the value of the following month. Therefore, there are actually fewer independent points contributing to the standard error of a linear regression, which assumes a series of independent data.

The partial autocorrelation functions of the residual time series ε_i for several stations are shown in Figure 8. The partial autocorrelation function shows the correlation of a series with itself at increasing lags, after the correlations at the intervening lags have been removed. Values above or below the horizontal lines on the plots are statistically significant. For all stations, the lag 1 autocorrelation is the largest and is always statistically significant ranging between 0.2 and 0.9.

At many stations, none of the higher lags are statistically significant; at other stations, some higher lags are marginally significant but less than the lag 1 autocorrelation.

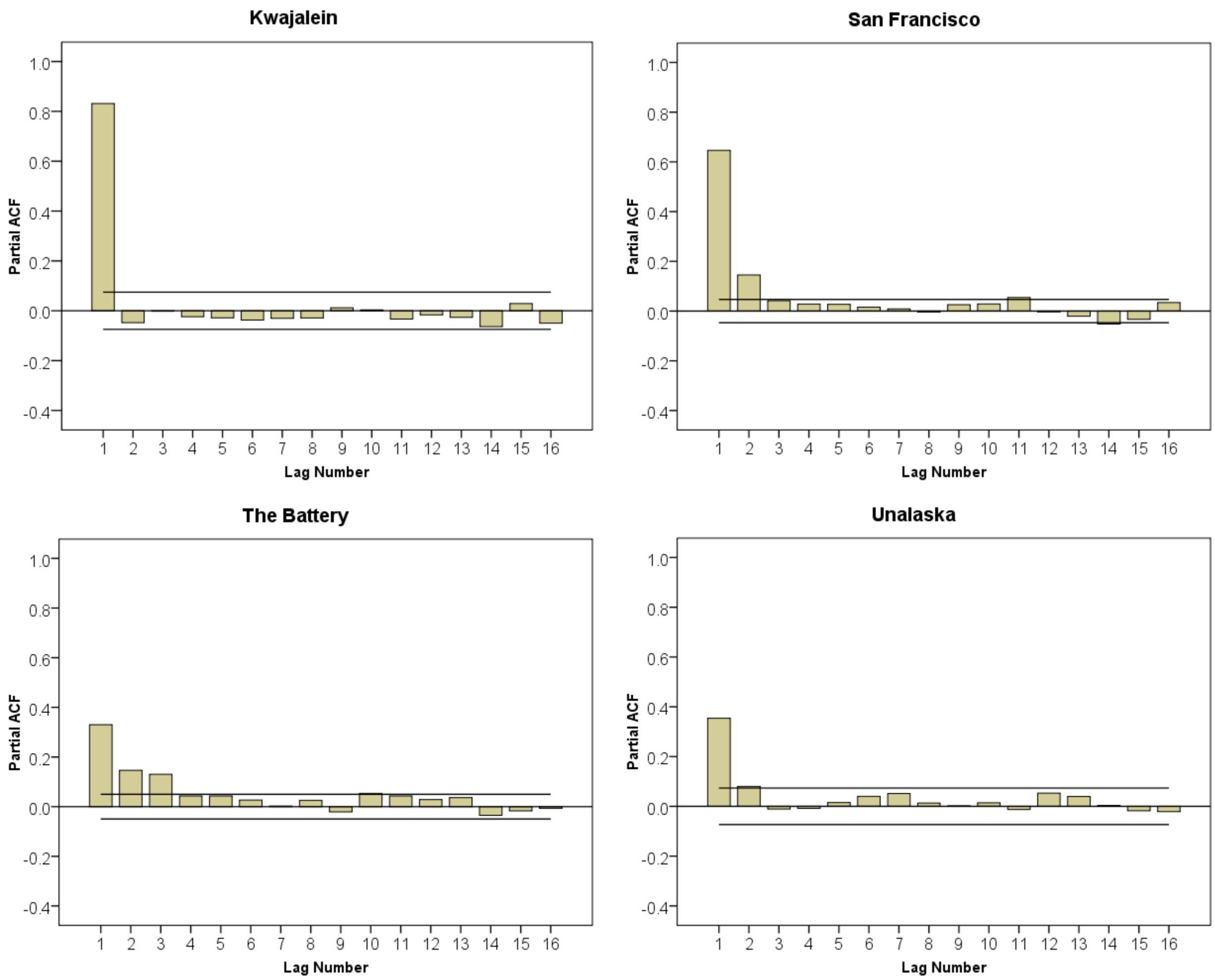


Figure 8. Partial autocorrelation functions of residual time series versus lag in months. Values above or below the horizontal lines are statistically significant.

Therefore, following Zervas (2001), the monthly MSL data y_i are characterized as an autoregressive process of order 1 as

$$y_i = bt_i + m_j + \rho_1 (y_{i-1} - bt_{i-1} - m_{j-1}) + \varepsilon_i \tag{4}$$

where ρ_1 is the lag 1 autoregressive coefficient representing the part of the time series predictable from the previous month's residual, and ε_i is the error representing the random unpredictable part of the residual. ρ_1 ranges between -1 and +1 with 0 meaning the next value is completely unpredictable (i.e., the residual is a random time series) and +1 meaning that the best guess for the next residual is the current residual.

Since an extra parameter ρ_1 is being solved for with the same amount of data, the uncertainty of the solution is greater. The amount that the standard error of the trend s_b is increased when using the autoregressive solution instead of the linear regression solution can be approximated by the square root of the variance inflation factor (Storch and Zwiers 2001, Wilks 2006) as

$$s_{b(autoregression)} / s_{b(linear\ regression)} = [\ (1 + \rho_1) / (1 - \rho_1)\ ]^{1/2} \tag{5}$$

The effect of increasing serial correlation on the standard error is shown in Table 3. A larger standard error results in wider error bars associated with the derived parameter. Therefore, for example, if the lag 1 autoregressive coefficient is 0.6, the correct standard error should be 2 times the standard error that would be obtained by applying a simple linear regression.

Table 3. Effect of serial correlation of time series residuals on standard errors

Autoregressive Coefficient	Variance Inflation Factor	Ratio of Standard Errors
0	1.0	1.0
0.2	1.5	1.225
0.4	2.333	1.528
0.6	4.0	2.0
0.8	9.0	3.0

For some of the stations, there was an apparent datum shift or a seismic offset in the time series. For an apparent datum shift, the trend should be the same before and after the shift. For an earthquake, there may be a detectable seismic offset and/or the trend has the possibility of being different before and after the earthquake. It can be assumed that the average seasonal cycle does not change as a result of these events.

To incorporate an unknown datum shift at a known time into the solution, the equation solved for is

$$y_i = bt_i + m_j + df_i + \rho_1\ (y_{i-1} - bt_{i-1} - m_{j-1} - df_{i-1}) + \varepsilon_i \tag{6}$$

where d is the magnitude of the datum shift and f_i is a step function with a value of 1 before the shift and 0 after the shift.

To incorporate an earthquake at a known time into the solution, the equation solved for is

$$y_i = b_1 f_i t_i + b_2(1\text{-}f_i)t_i + m_j + df_i \; + \; \rho_1 \,(y_{i\text{-}1} - b_1 f_{i\text{-}1} t_{i\text{-}1} - b_2(1\text{-}f_{i\text{-}1})t_{i\text{-}1} - m_{j\text{-}1} - df_{i\text{-}1}) + \varepsilon_i \tag{7}$$

where d is the magnitude of the seismic offset, b_1 is the trend before the earthquake, b_2 is the trend after the earthquake, and f_i is a step function with a value of 1 before the offset and 0 after the offset.

LINEAR MEAN SEA LEVEL TRENDS

The 128 selected NWLON stations were analyzed using the methods described in the previous section and the resulting MSL trends are listed in Table 4, which gives the first year and last year of data, the year range, the linear trend with its 95% confidence interval, and the autoregressive coefficient with its 95% confidence interval. The 95% confidence intervals are 1.96 times the standard error above and below the derived value. The 95% confidence intervals are narrowest for the stations with the longest year range of data. If a seismic offset and an associated change in trend are included in the analysis, both pre-seismic and post-seismic trends are given in Table 4. Appendix II contains plots of the monthly MSLs after the average seasonal cycle has been removed, the calculated trend line, and its 95% confidence interval. A 5-month running average is also displayed to smooth out month-to-month variability and focus more attention on longer-term anomalies. Solid vertical lines indicate the times of any nearby major earthquakes. Periods of questionable data that appear to be offset are bracketed by dashed vertical lines.

The monthly MSL data plotted in Appendix II are relative to the MSL datum presently in effect. For most stations, it is the MSL datum for the NTDE of 1983-2001. This is apparent in the plots, as the calculated trends appear to cross zero around 1992, the middle year of the NTDE. For stations where sea level has been rapidly rising or falling, CO-OPS has created special 5-year MSL datums. For those station's plots, the calculated trends cross zero near the middle of those periods. The Galveston Pier 21, Galveston Pleasure Pier, Freeport, Anchorage, and Unalaska MSL datums are for 1997-2001. The Grand Isle, Rockport, Juneau, Skagway, Yakutat, Seldovia, Nikiski, and Kodiak Island MSL datums are for 2002-2006. Eugene Island has no recent data so it is presented on its old 1960-1978 MSL datum. Guantanamo Bay has no established datum so it is presented on its own arbitrary station datum.

The main difference between the trends in Table 4 and the trends in the previous report (Zervas 2001), is the reduction in the widths of the 95% confidence intervals achieved by using seven additional years of data. Many of the shortest-period U.S. west coast stations have slightly lower trends using data up to 2006 compared to trends using data up to 1999. The reason is that the high water levels in 1997-1998 due to a strong El Niño event resulted in a small upward bias in the previously calculated trends, although none of the differences are statistically significant at the 95% confidence level. Only five stations have a new trend that is outside of the 95% confidence intervals previously calculated in Zervas (2001). These stations are Springmaid Pier, Freeport, Yakutat, Cordova, and Valdez and all have lower trends than in Zervas (2001).

Most of the U.S. east coast stations that are compared in Figure 9 have been in operation for many decades, making it possible to detect statistically significant differences in trends among the stations. All of the trends are above the global 20th century average of 1.7 mm/yr indicating that some land subsidence is included in most of the trends. There are higher trends in the mid-Atlantic coastal region from New Jersey to Virginia than in the regions to the north or to the south. This pattern is often attributed to the ongoing collapse of the peripheral bulge that was formed as a result of visco-elastic lithospheric compensation during the previous ice age, due to the weight of the ice sheet (Douglas 1991, Davis and Mitrovica 1996). The highest east coast trend is 6.05 mm/yr at the Chesapeake Bay Bridge Tunnel station which is located on a man-made structure and therefore, its rate may not be representative of a wider area.

The MSL trends at the U.S. west coast and Alaska stations compared in Figure 10 are much more spatially variable due to tectonic activity at plate boundaries. There are also more shorter-period stations with correspondingly wider 95% confidence intervals. Most of the trends are close to or below the global 20th century rate of 1.7 mm/yr with the exceptions of Rincon Island, North Spit, South Beach, and Cordova where some localized land subsidence is likely to be occurring. Rapidly falling sea levels indicate substantial uplift at Juneau and Skagway due to localized glacial melting, and at Seldovia, Nikiski, Kodiak Island, and Unalaska due to post-seismic tectonic processes. Both processes may be occurring at Yakutat. Smaller rates of vertical land uplift are apparent at various other locations in Alaska and in Washington, Oregon, and California. The most negative MSL trend at any NWLON station is -17.12 mm/yr at Skagway located at the upper end of a glacial fjord.

Most of the station trends for the tropical Pacific, Bermuda, the Gulf of Mexico, and the Caribbean, compared in Figure 11, are reasonably close to the global 20th century rate with the exception of the stations in Louisiana and Texas where substantial subsidence is occurring. The western part of the U.S. Gulf coast has been experiencing sediment loading, soil compaction, and high rates of oil, gas, and groundwater extraction. The highest MSL trends are at Grand Isle and Eugene Island in Louisiana. The trend at Hilo is somewhat higher than the trends at the other Hawaiian stations perhaps from crustal subsidence due to active volcanic loading of the Pacific plate. The negative trend at Guam is only for the period before the 1993 8.0-magnitude earthquake when a 10-cm offset is apparent in the detided hourly water level record. Since 1993, Guam has experienced a large positive MSL trend.

The autoregressive coefficients for all the stations are compared in Figures 12-14. The autoregressive coefficient can range between -1 and +1 and indicates how predictable a monthly MSL residual is from the previous month's MSL residual. Values near +1 indicate that if one month's residual is positive, the next month's residual is also highly likely to be positive; values near -1 indicate that if one month's residual is positive, the next month's residual is highly likely to be negative. The highest positive values are found at stations dominated by the El Niño Southern Oscillation (ENSO) with very little month-to-month variability. The characteristic effects of ENSO on Pacific Ocean water level variability will be discussed later in this report.

The autoregressive coefficients for U.S. east coast stations range between 0.3 and 0.5. For U.S. west coast stations, autoregressive coefficients are near 0.7 at stations from San Diego to the San Francisco Bay area which are dominated by the ENSO signal. They fall back to the 0.3-0.5

range for northern California, Oregon, Washington, and Alaska stations which also contain ENSO forcing but have substantial month-to-month variability. Most of the Gulf coast stations have autoregressive coefficients varying between 0.4 and 0.6 with values slightly increasing from east to west. The Hawaiian and Caribbean autoregressive coefficients are clustered around 0.7, while Johnston Atoll, Midway Atoll, Wake Island, and Bermuda have smaller values near 0.5 due to greater month-to-month variability. The highest autoregressive coefficients, over 0.8, are found at the west and south Pacific stations (Guam, Pago Pago, Kwajalein, and Chuuk) that are dominated by the ENSO signal, as will be demonstrated later in this report.

Table 4. Linear MSL trends for all monthly data up to 2006

Station Number	Station Name	First Year	Last Year	Year Range	MSL Trend in mm/yr and +/- 95% Conf. Interval		Autoregressive Coefficient and +/- 95% Conf. Interval	
1611400	Nawiliwili	1955	2006	52	1.53	0.59	0.65	0.06
1612340	Honolulu	1905	2006	102	1.50	0.25	0.74	0.04
1612480	Mokuoloe	1957	2006	50	1.31	0.72	0.71	0.06
1615680	Kahului	1947	2006	60	2.32	0.53	0.75	0.05
1617760	Hilo	1927	2006	80	3.27	0.35	0.63	0.05
1619000	Johnston Atoll	1947	2003	57	0.75	0.56	0.43	0.07
1619910	Midway Atoll	1947	2006	60	0.70	0.54	0.57	0.06
1630000	Guam (Pre EQ)	1948	1993	46	-1.05	1.72	0.86	0.04
1630000	Guam (Post EQ)	1993	2006	14	8.58	8.93		
1770000	Pago Pago	1948	2006	59	2.07	0.90	0.82	0.04
1820000	Kwajalein	1946	2006	61	1.43	0.81	0.84	0.04
1840000	Chuuk	1947	1995	49	0.60	1.78	0.85	0.05
1890000	Wake Island	1950	2006	57	1.91	0.59	0.47	0.07
2695540	Bermuda	1932	2006	75	2.04	0.47	0.45	0.06
8410140	Eastport	1929	2006	78	2.00	0.21	0.45	0.06
8413320	Bar Harbor	1947	2006	60	2.04	0.26	0.34	0.07
8418150	Portland	1912	2006	95	1.82	0.17	0.45	0.05
8419870	Seavey Island	1926	2001	76	1.76	0.30	0.37	0.07
8443970	Boston	1921	2006	86	2.63	0.18	0.39	0.06
8447930	Woods Hole	1932	2006	75	2.61	0.20	0.39	0.06
8449130	Nantucket Island	1965	2006	42	2.95	0.46	0.33	0.08
8452660	Newport	1930	2006	77	2.58	0.19	0.35	0.06
8454000	Providence	1938	2006	69	1.95	0.28	0.47	0.07
8461490	New London	1938	2006	69	2.25	0.25	0.39	0.06
8467150	Bridgeport	1964	2006	43	2.56	0.58	0.39	0.08
8510560	Montauk	1947	2006	60	2.78	0.32	0.35	0.07
8514560	Port Jefferson	1957	1992	36	2.44	0.76	0.39	0.09
8516945	Kings Point / Willets Point	1931	2006	76	2.35	0.24	0.32	0.06
8518750	The Battery	1856	2006	151	2.77	0.09	0.33	0.05
8531680	Sandy Hook	1932	2006	75	3.90	0.25	0.32	0.06
8534720	Atlantic City	1911	2006	96	3.99	0.18	0.30	0.06

Table 4. Linear MSL trends for all monthly data up to 2006								
Station Number	**Station Name**	**First Year**	**Last Year**	**Year Range**	**MSL Trend in mm/yr and +/- 95% Conf. Interval**		**Autoregressive Coefficient and +/- 95% Conf. Interval**	
8536110	Cape May	1965	2006	42	4.06	0.74	0.38	0.09
8545240	Philadelphia	1900	2006	107	2.79	0.21	0.38	0.05
8551910	Reedy Point	1956	2006	51	3.46	0.66	0.42	0.09
8557380	Lewes	1919	2006	88	3.20	0.28	0.34	0.07
8570283	Ocean City	1975	2006	32	5.48	1.67	0.46	0.12
8571892	Cambridge	1943	2006	64	3.48	0.39	0.42	0.08
8573927	Chesapeake City	1972	2006	35	3.78	1.56	0.55	0.13
8574680	Baltimore	1902	2006	105	3.08	0.15	0.32	0.05
8575512	Annapolis	1928	2006	79	3.44	0.23	0.35	0.06
8577330	Solomons Island	1937	2006	70	3.41	0.29	0.37	0.06
8594900	Washington	1924	2006	83	3.16	0.35	0.37	0.06
8632200	Kiptopeke	1951	2006	56	3.48	0.42	0.35	0.07
8635150	Colonial Beach	1972	2003	32	4.78	1.21	0.42	0.09
8635750	Lewisetta	1974	2006	33	4.97	1.04	0.41	0.09
8637624	Gloucester Point	1950	2003	54	3.81	0.47	0.34	0.07
8638610	Sewells Point	1927	2006	80	4.44	0.27	0.34	0.06
8638660	Portsmouth	1935	1987	53	3.76	0.45	0.29	0.08
8638863	Chesapeake Bay Br. Tunnel	1975	2006	32	6.05	1.14	0.37	0.10
8652587	Oregon Inlet Marina	1977	2006	30	2.82	1.76	0.41	0.14
8656483	Beaufort	1953	2006	54	2.57	0.44	0.36	0.08
8658120	Wilmington	1935	2006	72	2.07	0.40	0.49	0.06
8659084	Southport	1933	2006	74	2.08	0.46	0.46	0.09
8661070	Springmaid Pier	1957	2006	50	4.09	0.76	0.50	0.08
8665530	Charleston	1921	2006	86	3.15	0.25	0.40	0.06
8670870	Fort Pulaski	1935	2006	72	2.98	0.33	0.38	0.06
8720030	Fernandina Beach	1897	2006	110	2.02	0.20	0.41	0.05
8720218	Mayport	1928	2006	79	2.40	0.31	0.42	0.06
8721120	Daytona Beach Shores	1925	1983	59	2.32	0.63	0.50	0.09
8723170	Miami Beach	1931	1981	51	2.39	0.43	0.39	0.08
8723970	Vaca Key	1971	2006	36	2.78	0.60	0.37	0.09
8724580	Key West	1913	2006	94	2.24	0.16	0.47	0.05
8725110	Naples	1965	2006	42	2.02	0.60	0.52	0.08
8725520	Fort Myers	1965	2006	42	2.40	0.65	0.48	0.08
8726520	St. Petersburg	1947	2006	60	2.36	0.29	0.41	0.07
8726724	Clearwater Beach	1973	2006	34	2.43	0.80	0.49	0.09
8727520	Cedar Key	1914	2006	93	1.80	0.19	0.42	0.06
8728690	Apalachicola	1967	2006	40	1.38	0.87	0.51	0.08
8729108	Panama City	1973	2006	34	0.75	0.83	0.46	0.09
8729840	Pensacola	1923	2006	84	2.10	0.26	0.52	0.05
8735180	Dauphin Island	1966	2006	41	2.98	0.87	0.49	0.09
8761724	Grand Isle	1947	2006	60	9.24	0.59	0.64	0.06
8764311	Eugene Island	1939	1974	36	9.65	1.24	0.58	0.08
8770570	Sabine Pass	1958	2006	49	5.66	1.07	0.61	0.07

Table 4. Linear MSL trends for all monthly data up to 2006

Station Number	Station Name	First Year	Last Year	Year Range	MSL Trend in mm/yr and +/- 95% Conf. Interval		Autoregressive Coefficient and +/- 95% Conf. Interval	
8771450	Galveston Pier 21	1908	2006	99	6.39	0.28	0.53	0.05
8771510	Galveston Pleasure Pier	1957	2006	50	6.84	0.81	0.54	0.07
8772440	Freeport	1954	2006	53	4.35	1.12	0.50	0.07
8774770	Rockport	1948	2006	59	5.16	0.67	0.54	0.07
8778490	Port Mansfield	1963	2006	44	1.93	0.97	0.54	0.08
8779751	Padre Island	1958	2006	49	3.48	0.75	0.55	0.08
8779770	Port Isabel	1944	2006	63	3.64	0.44	0.50	0.06
9410170	San Diego	1906	2006	101	2.06	0.20	0.71	0.04
9410230	La Jolla	1924	2006	83	2.07	0.29	0.71	0.05
9410580	Newport Beach	1955	1993	39	2.22	1.04	0.76	0.06
9410660	Los Angeles	1923	2006	84	0.83	0.27	0.70	0.04
9410840	Santa Monica	1933	2006	74	1.46	0.40	0.73	0.05
9411270	Rincon Island	1962	1990	29	3.22	1.66	0.75	0.07
9411340	Santa Barbara	1973	2006	34	1.25	1.82	0.79	0.09
9412110	Port San Luis	1945	2006	62	0.79	0.48	0.70	0.05
9413450	Monterey	1973	2006	34	1.34	1.35	0.72	0.07
9414290	San Francisco	1854	1897	44	2.05	0.85	0.65	0.04
9414290	San Francisco	1897	2006	110	2.01	0.21		
9414523	Redwood City	1974	2006	33	2.06	3.12	0.79	0.11
9414750	Alameda	1939	2006	68	0.82	0.51	0.70	0.05
9415020	Point Reyes	1975	2006	32	2.10	1.52	0.67	0.08
9415144	Port Chicago	1976	2006	31	2.08	2.74	0.72	0.07
9418767	North Spit	1977	2006	30	4.73	1.58	0.56	0.09
9419750	Crescent City	1933	2006	74	-0.65	0.36	0.48	0.06
9431647	Port Orford	1977	2006	30	0.18	2.18	0.54	0.10
9432780	Charleston	1970	2006	37	1.29	1.15	0.50	0.08
9435380	South Beach	1967	2006	40	2.72	1.03	0.48	0.08
9437540	Garibaldi	1970	2006	37	1.98	1.82	0.40	0.16
9439040	Astoria	1925	2006	82	-0.31	0.40	0.45	0.06
9440910	Toke Point	1973	2006	34	1.60	1.38	0.39	0.09
9443090	Neah Bay	1934	2006	73	-1.63	0.36	0.34	0.06
9444090	Port Angeles	1975	2006	32	0.19	1.39	0.45	0.09
9444900	Port Townsend	1972	2006	35	1.98	1.15	0.49	0.08
9447130	Seattle	1898	2006	109	2.06	0.17	0.39	0.05
9449424	Cherry Point	1973	2006	34	0.82	1.20	0.48	0.09
9449880	Friday Harbor	1934	2006	73	1.13	0.33	0.42	0.06
9450460	Ketchikan	1919	2006	88	-0.19	0.27	0.36	0.06
9451600	Sitka	1924	2006	83	-2.05	0.32	0.36	0.06
9452210	Juneau	1936	2006	71	-12.92	0.43	0.40	0.06
9452400	Skagway	1944	2006	63	-17.12	0.65	0.46	0.07
9453220	Yakutat	1940	2006	67	-6.44	0.47	0.41	0.06
9453220	Yakutat (Pre EQ)	1940	1979	40	-4.81	0.89	0.32	0.07
9453220	Yakutat (Post EQ)	1979	2006	28	-11.53	1.46		

Table 4. Linear MSL trends for all monthly data up to 2006								
Station Number	**Station Name**	**First Year**	**Last Year**	**Year Range**	**MSL Trend in mm/yr and +/- 95% Conf. Interval**		**Autoregressive Coefficient and +/- 95% Conf. Interval**	
9454050	Cordova (Pre EQ)	1949	1961	13	5.01	10.92	0.35	0.08
9454050	Cordova (Post EQ)	1964	2006	43	5.76	0.87		
9454240	Valdez	1973	2006	34	-2.52	1.36	0.37	0.10
9455090	Seward (Pre EQ)	1925	1964	40	-0.11	1.08	0.34	0.06
9455090	Seward (Post EQ)	1964	2006	43	-1.74	0.91		
9455500	Seldovia	1964	2006	43	-9.45	1.10	0.41	0.08
9455760	Nikiski	1973	2006	34	-9.80	1.50	0.22	0.16
9455920	Anchorage	1972	2006	35	0.88	1.54	0.45	0.10
9457292	Kodiak Island (Pre EQ)	1949	1964	16	1.19	3.70	0.34	0.09
9457292	Kodiak Island (Post EQ)	1975	2006	32	-10.42	1.33		
9459450	Sand Point	1972	2006	35	0.92	1.32	0.31	0.10
9461380	Adak Island (Pre EQ)	1943	1957	15	2.45	3.61	0.30	0.07
9461380	Adak Island (Post EQ)	1957	2006	50	-2.75	0.54		
9462620	Unalaska (Pre EQ)	1934	1957	24	-0.57	2.16	0.36	0.07
9462620	Unalaska (Post EQ)	1957	2006	50	-5.72	0.67		
9731158	Guantanamo Bay	1937	1971	35	1.64	0.80	0.65	0.08
9751401	Lime Tree Bay	1977	2006	30	1.74	1.20	0.65	0.09
9751639	Charlotte Amalie	1975	2006	32	1.20	0.96	0.72	0.07
9755371	San Juan	1962	2006	45	1.65	0.52	0.66	0.07
9759110	Magueyes Island	1955	2006	52	1.35	0.37	0.68	0.06

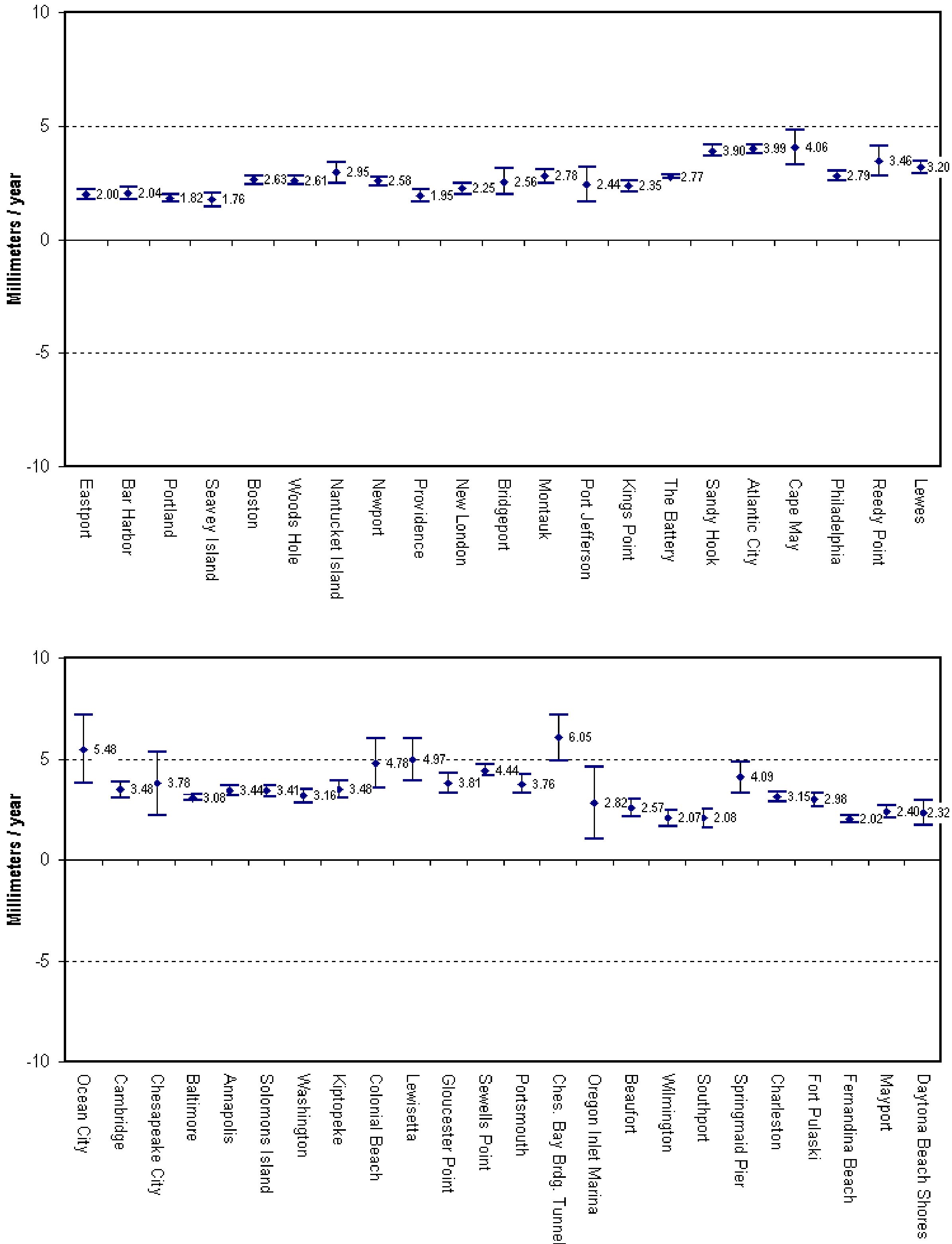


Figure 9. MSL trends with 95% confidence intervals (mm/yr) for all monthly data up to 2006 for U.S. east coast stations.

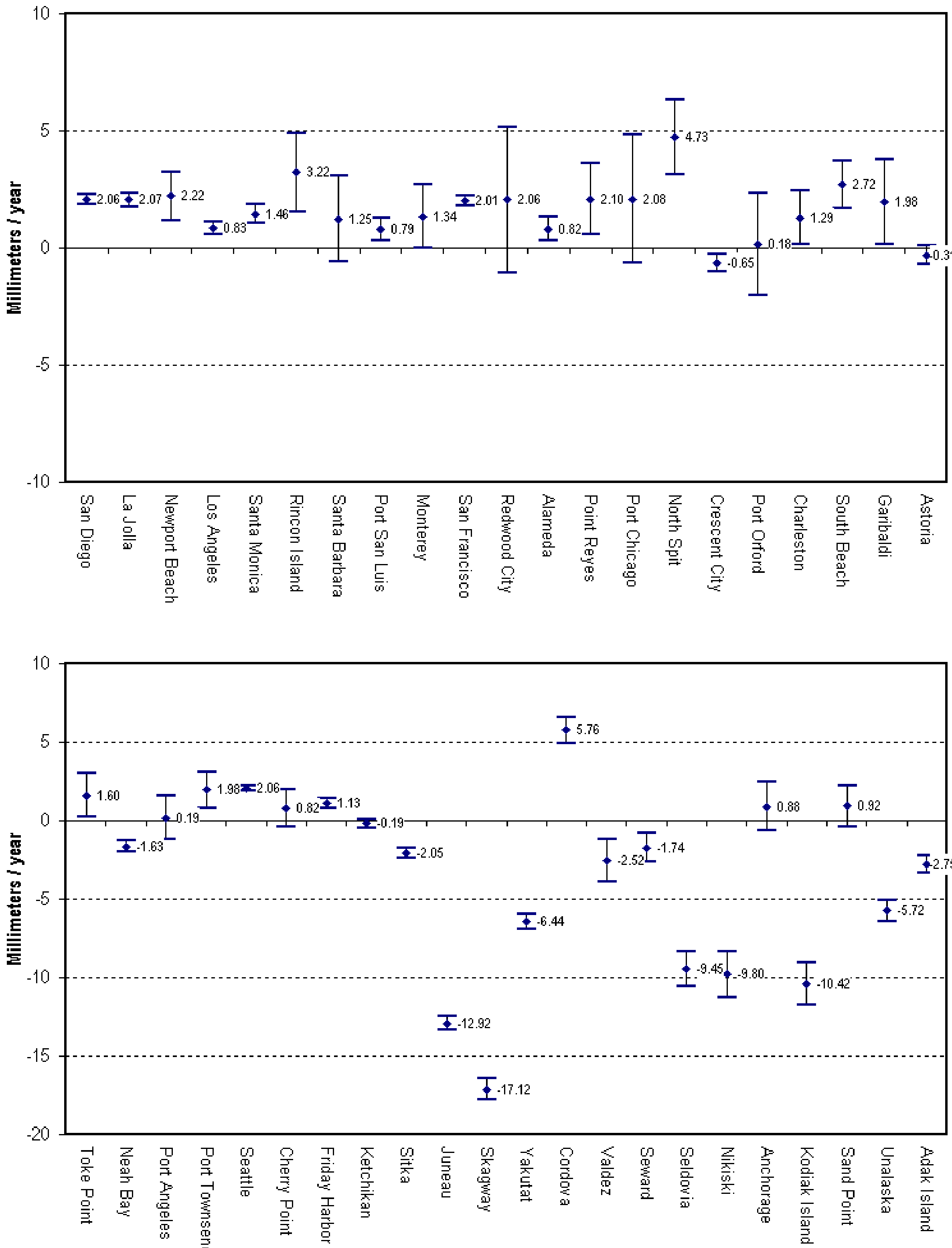


Figure 10. MSL trends with 95% confidence intervals (mm/yr) for all monthly data up to 2006 for U.S. west coast stations and Alaska.

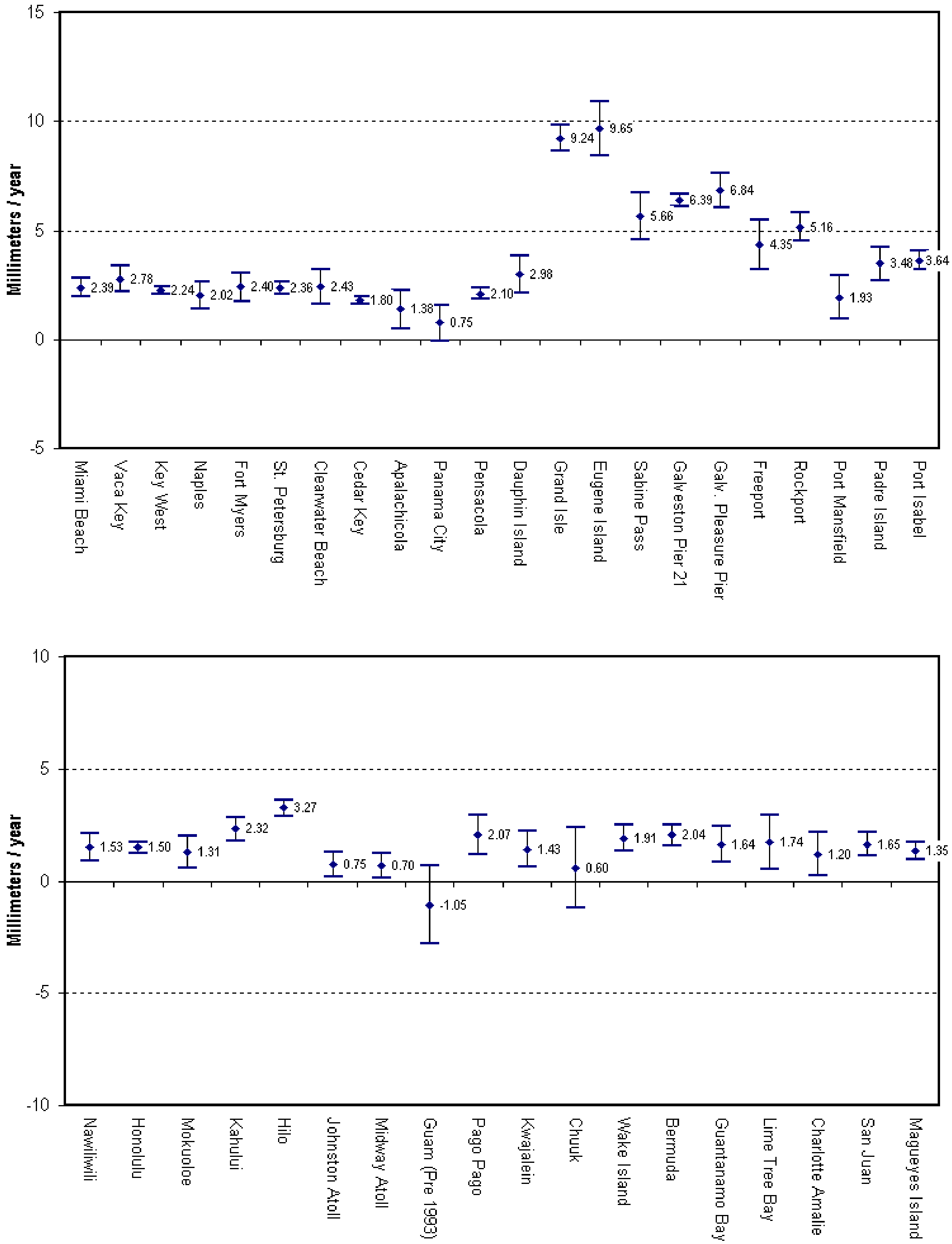


Figure 11. MSL trends and 95% confidence intervals (mm/yr) for all monthly data up to 2006 for Gulf of Mexico, tropical Pacific, Bermuda, and Caribbean stations.

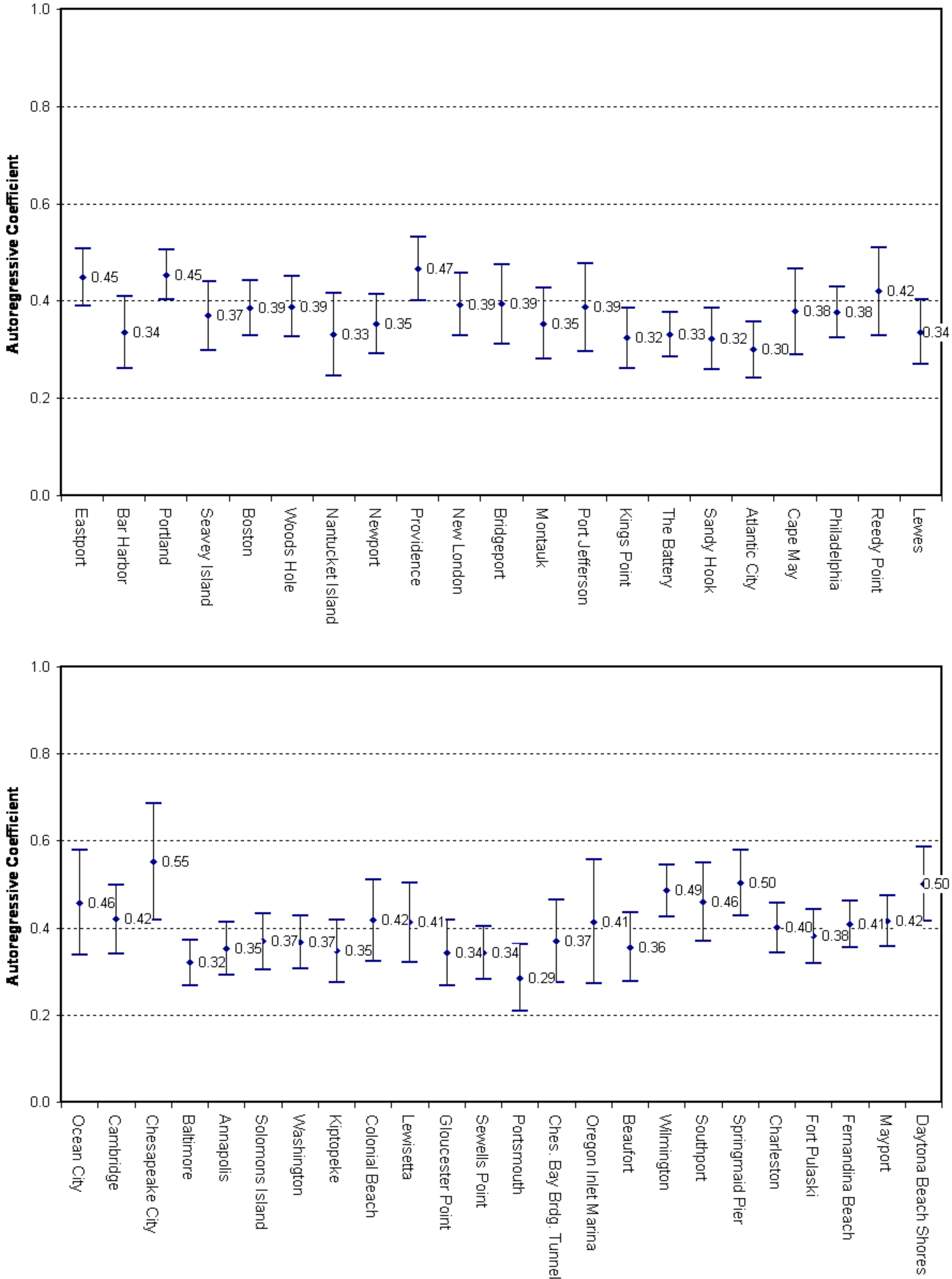


Figure 12. Autoregressive coefficient with 95% confidence interval for U.S. east coast stations.

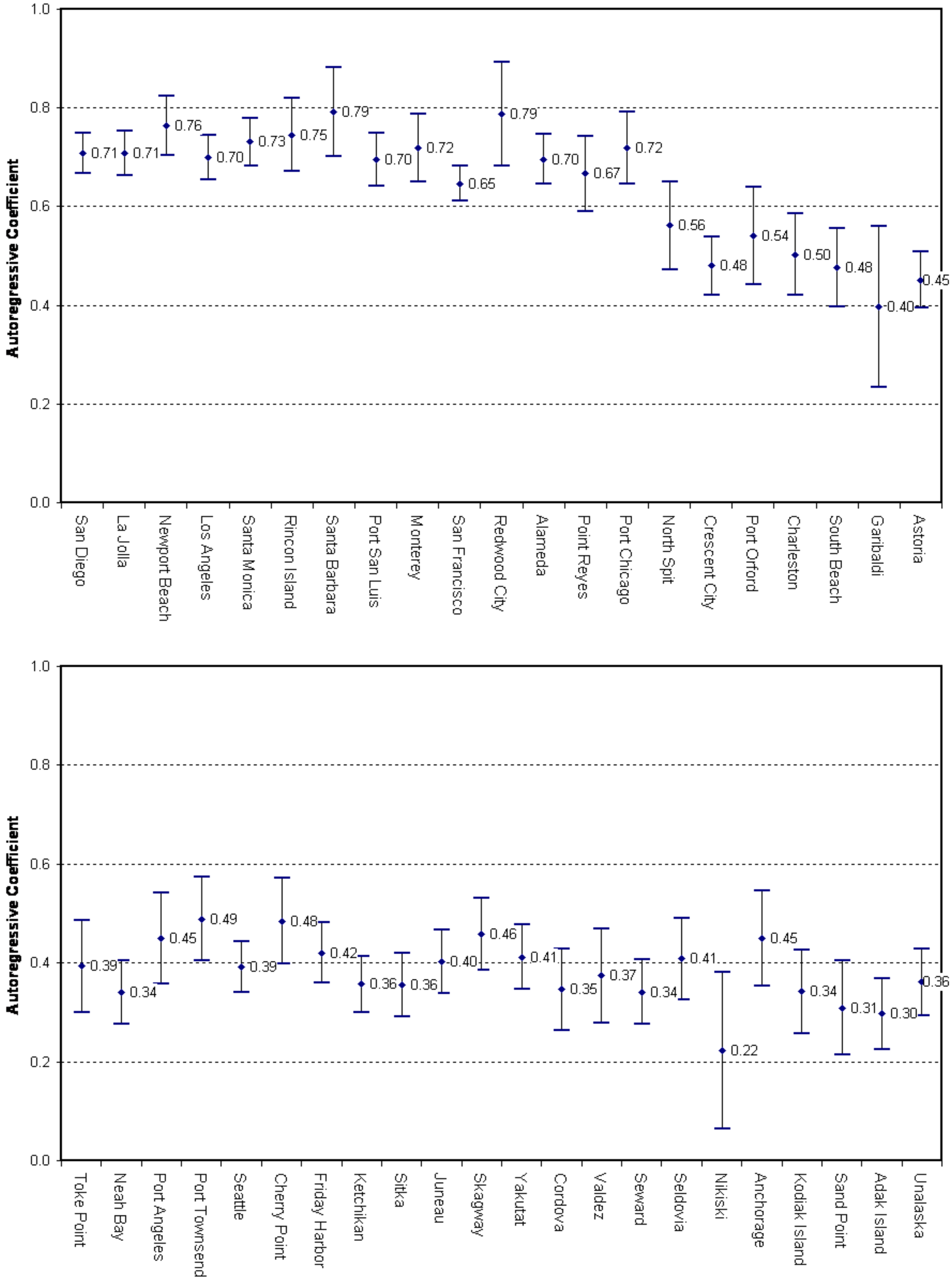


Figure 13. Autoregressive coefficient with 95% confidence interval for U.S. west coast and Alaska stations.

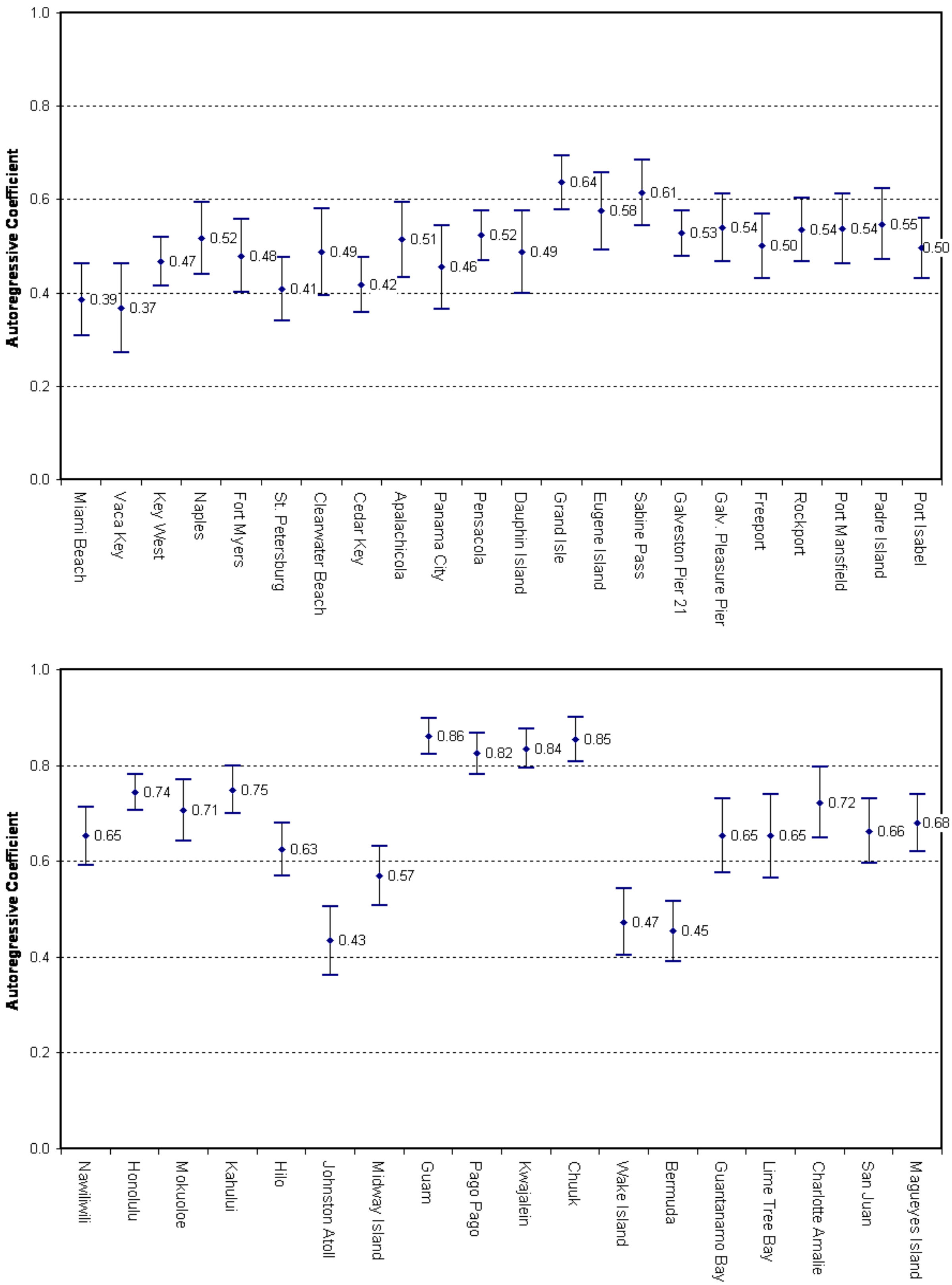


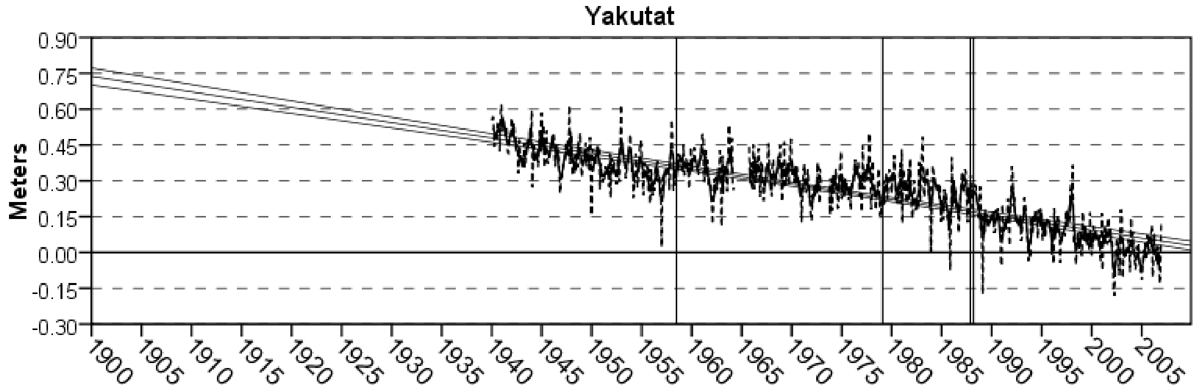
Figure 14. Autoregressive coefficient with 95% confidence interval for Gulf of Mexico, tropical Pacific, Bermuda, and Caribbean stations.

At six of the NWLON stations, there was clear evidence of a seismic offset and, for these stations, an offset and a change in trend are included in the analyses. These events are the August 1993 earthquake affecting Guam, the March 1964 earthquake affecting Cordova, Seward, and Kodiak Island, and the March 1957 earthquake affecting Unalaska and Adak Island. For Guam, the high post-seismic trend of 8.58 +/- 8.93 mm/yr is based on only 14 years of data and, therefore, has a large uncertainty. Satellite altimetry measurements since 1993 show comparatively high sea level trends in the western Pacific region (Cazenave and Nerem 2004), which suggests that the rate at Guam may be due to rapid absolute sea level rise rather than rapid post-seismic land subsidence. For Cordova, Kodiak Island, Unalaska, and Adak Island, the pre-seismic trends are based on only 13 to 24 years of data and therefore are highly uncertain. None of these trends are statistically different from zero at the 95% confidence level. The pre-seismic trend at Seward is based on 40 years of data and is therefore better determined, but it is also not statistically different from zero. All of the post-seismic trends for the Alaskan stations are based on 32 to 50 years of data and are statistically different from zero.

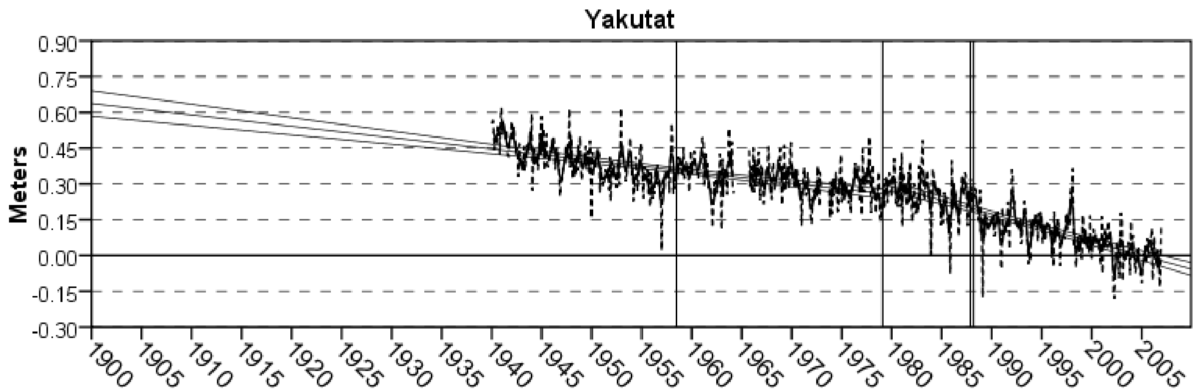
The record at the Yakutat station appears to be a special case. When a single line is fitted to the entire time series, a trend of -6.44 mm/yr is obtained. Examination of the residual time series and comparisons with residuals at nearby stations strongly suggest the possibility of nonlinearity at Yakutat. One possible cause is increasing glacial melting in the region around Yakutat, leading to increasing elastic rebound of the lithosphere and more rapidly falling sea levels.

Another possible cause is regional tectonic activity. There were four major earthquakes in the region in July 1958, February 1979, November 1987, and March 1988, and it is possible that offsets or changes in trends may be associated with one or more of these events. Yakutat is at the border between the seismic zones of the 1958 and 1979 earthquakes. It is possible that there was a steeper trend before the 1958 earthquake, a flatter trend between 1958 and either the 1979 or the 1987-1988 events, and then a steeper trend up to the present.

In order to avoid over-fitting the Yakutat time series with a series of short, highly uncertain trends, only one alternative is presented to fitting the entire series with a single line. One offset and a change in trend are modeled at the time of the February 1979 earthquake. The time series further west at the Cordova and Valdez stations also suggest a possibility of a change in trend at that time or at the time of the 1987-1988 earthquakes. When two trends are modeled at Yakutat, the pre-1979 trend is -4.81 mm/yr and the post-1979 trend is -11.53 mm/yr (Figure 15).



a)



b)

Figure 15. Monthly MSL data for Yakutat after removal of the average seasonal cycle. Calculated trends are shown with 95% confidence intervals. Possible MSL trends for Yakutat are a) a single trend of -6.44 +/- 0.47 mm/yr or b) a February 1979 offset and change in trend from -4.81 +/- 0.89 mm/yr to -11.53 +/- 1.46 mm/yr.

In the previous report (Zervas 2001), comparisons of the Freeport time series with nearby stations showed that there may have been an apparent datum shift on January 1972. Further examination of the station differences, indicates that there could have been either an instantaneous shift or a short period of extremely rapid subsidence in 1969-1971. There has been measureable subsidence in the Freeport area due to groundwater withdrawal (Sandeen and Wesselman 1973). The series at Freeport is again modeled with an offset at January 1972 and no associated change in trend (Figure 16). The resulting trend is 4.35 mm/yr and the resulting offset is 0.190 m.

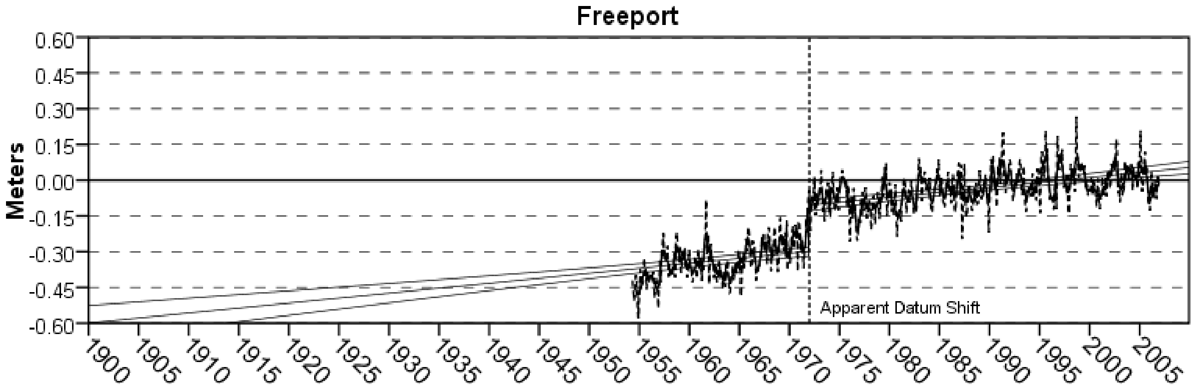


Figure 16. Monthly MSL data for Freeport after removal of the average seasonal cycle. The trend of 4.35 +/- 1.12 mm/yr was calculated with an apparent datum shift of 0.190 m on January 1972 and is shown with its 95% confidence interval.

In the previous report (Zervas 2001), the long continuous time series for San Francisco was initially fitted with a single trend; however, it seemed more likely that there was some non-linearity in the time series, with a greater trend discernable in the 20th century than in the 19th century and apparently falling sea levels in the 50-year period centered around 1900. The station is only 8 km from the San Andreas Fault which slipped in a major earthquake in April 1906. Although there was no discernable offset at the time of the earthquake (Lawson and Reid 1908), the series was fitted with a lower pre-seismic and a higher post-seismic trend implying a tectonic cause for the change in trend (Zervas 2001).

Further investigation of the residual time series has shown that there was a discernable offset in 1897. The entire San Francisco series (Smith 1980, Smith 2002) had been put together by combining data collected from three locations at Fort Point (1854-1877), Sausalito (1877-1897), and the Presidio (since 1897). The timing of the apparent offset coincided with the time when the station was moved back across the Golden Gate from Sausalito to the Presidio, which raises a question about the accuracy of the connection between the two series. In this report, the series is modeled with an apparent datum shift in September 1897 and separate trends before and after that date, instead of with a seismic offset in April 1906. The trends before and after the apparent datum shift are nearly identical (Figure 17).

Since the timing of the apparent offset coincided with the time when the station was moved across the Golden Gate, the method used to link the three series together was re-examined. At each location, measurements were recorded on an arbitrary tide gauge zero level known as the station datum. There was a 9-month overlap period in 1877 while the station was first transferred from Fort Point to Sausalito. Six months of simultaneous tidal measurements showed a difference of 0.42 ft (0.128 m). A leveling line across the Golden Gate in 1877 showed that the station datum of the Sausalito gauge was 0.46 ft (0.140 m) above the station datum of the Fort

Point gauge. The station datum difference of 0.46 ft from the leveling line was used by Smith (1980) to combine the Fort Point and the Sausalito series.

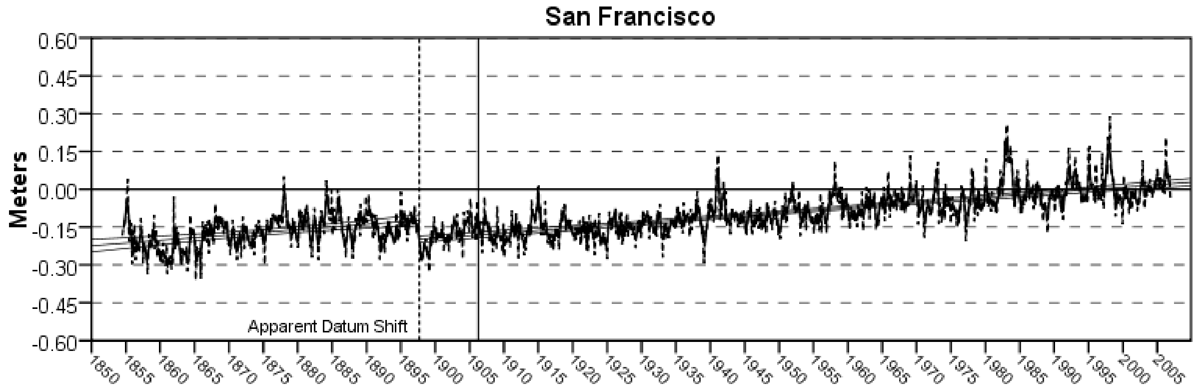


Figure 17. Monthly MSL data for San Francisco after removal of the average seasonal cycle. The trends before and after an apparent datum shift of 0.075 m on September 1897 are 2.05 +/- 0.85 mm/yr and 2.01 +/- 0.21 mm/yr. The time of the April 1906 earthquake is shown by the solid vertical line.

There was also a 1½-month overlap period when both stations were operating in 1897, when the station was transferred back across the Golden Gate from Sausalito to the Presidio. A comparison of simultaneous tidal measurements showed a difference of 0.129 ft (0.039 m). There was no leveling line conducted to connect the tidal bench marks around the Sausalito and the Presidio gauges in 1897. In 1906-1907, the U.S. Coast and Geodetic Survey carried out a campaign to resurvey bench marks in the San Francisco area following the April 1906 earthquake (Lawson and Reid 1908). The leveling line from the Sausalito bench marks to the Presidio bench marks showed that the Sausalito station datum was 0.25 ft (0.076 m) above the Presidio station datum and this value was used by Smith (1980, 2002) to combine the Fort Point/Sausalito series with the Presidio series.

By using the 1906-1907 leveling line to connect the stations datums in 1897, an implicit assumption is made that there was no differential vertical land motion between the Sausalito and the Presidio bench marks as a result of the 1906 earthquake; however, Lawson and Reid (1908) show small differential vertical land motions at various locations in the San Francisco area due to the earthquake. A group of four tidal bench marks near Fort Point, rose by an average of 0.071 m relative to the Presidio tide gauge zero level. More significantly, the primary tidal bench mark at Sausalito rose by 0.035 m and another Sausalito tidal bench mark rose by 0.040 m relative to the Presidio tide gauge zero level.

The implication of the differential vertical motions in the San Francisco region due to the earthquake is that the Sausalito bench marks rose, the Presidio bench marks fell, or they both moved in some manner to result in a 0.035 m relative difference. The Presidio tide gauge recorded water levels before, during, and after the earthquake without a break and actually recorded a small negative tsunami immediately after the earthquake; yet when the time series for 1906 is detided, no seismic offset can be discerned. Lawson and Reid (1908) also examined the Presidio monthly mean sea levels from 1897 to 1907 and could find no evidence of a seismic offset, although an offset as small as 0.035 m would be difficult to observe in the water level time series given the non-tidal oceanographic variability.

Therefore, the station datum difference of 0.076 m used by Smith (1980) to combine the Fort Point/Sausalito series with the Presidio series may include a seismic offset, which is introduced into the combined series in 1897 by using a post-seismic leveling line to make a pre-seismic connection. If the 0.035 m seismic movement of the Sausalito primary bench mark relative to the Presidio station datum is subtracted from the 0.076 m difference found by leveling after the earthquake, the result is 0.041 m. This value is extremely close to the 0.039 m difference for the two series found for the 1½-month period in 1897 when both gauges were operating simultaneously.

Therefore, the 0.039 m time series difference from 1897 when both gauges were in operation together may be a better value to use to link the two series than the 0.076 m value obtained from the leveling line completed 10 years later, after the earthquake. Figure 18 shows the series when the entire series is adjusted by 0.037 m (0.076 – 0.039) and fitted with a single linear trend. It is recommended that CO-OPS further investigate the comparison of simultaneous observations in 1897 and the 1906-07 leveling connection.

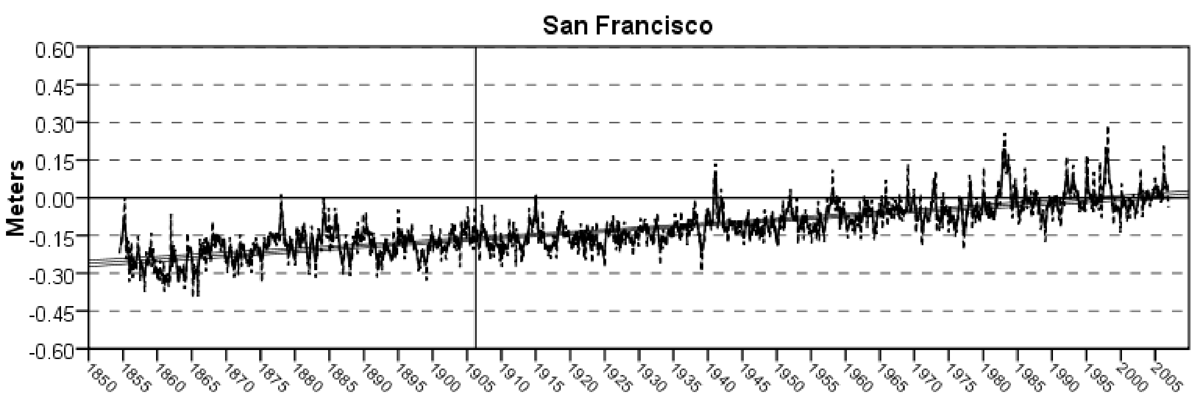


Figure 18. Monthly MSL data for San Francisco after removal of the average seasonal cycle and removal of an apparent datum shift of 0.037 m on September 1897. The total trend is 1.73 +/- 0.13 mm/yr. The time of the April 1906 earthquake is shown by the solid vertical line.

In 1977, a new water level station was established close to the location of the 1877-1897 Sausalito station. When tidal bench marks were being surveyed for the new station, the old 1877 primary bench mark was rediscovered and appeared to be undisturbed (Smith 1980, Smith 2002).

Data were collected for 2½ years until 1979 on a new station datum which was 2.72 ft (0.829 m) above the old Sausalito station datum. Using this information, the 1877-1897 data can be adjusted to the new station datum and a linear trend of 0.96 mm/yr is derived (Figure 19).

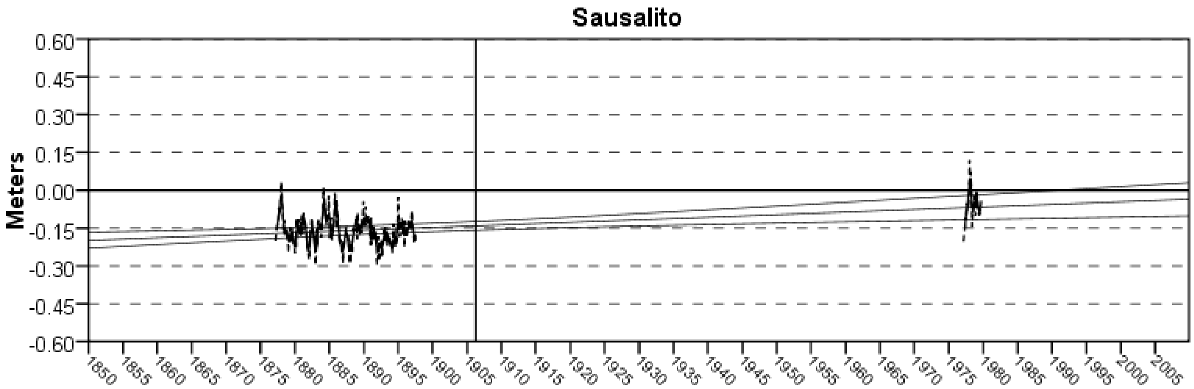


Figure 19. Monthly MSL data for Sausalito after removal of the average seasonal cycle. The total trend is 0.96 +/- 0.54 mm/yr. The time of the April 1906 earthquake is shown by the solid vertical line.

Fitting a single trend to the Sausalito data ignores the possibility of any seismic offset in 1906, but it is not possible to reasonably model the magnitude of an offset without any data immediately before and after the offset. If there was no seismic offset or even with a small offset of only 0.035 m, the trend is significantly lower than the 2.01 +/- 0.21 mm/yr trend at the Presidio since 1897. This is certainly possible due to differential tectonic uplift in between the multiple fault lines throughout the San Francisco Bay region. The station at Alameda about 15 km to the east was established in 1939, and has a trend of only 0.82 +/- 0.51 mm/yr, which is a statistically significant difference relative to the San Francisco trend.

AVERAGE SEASONAL MEAN SEA LEVEL CYCLE

By using monthly MSL data to derive the linear trends discussed in the previous section, twelve calendar monthly means are also obtained that define the average seasonal cycle. These monthly values for each station are listed in Table B in Appendix III and are also plotted in Appendix III with their 95% confidence intervals. The average seasonal cycle can be considered as the regular, repeatable variation over the course of a year which becomes more precisely defined as more years of data are accumulated.

The average seasonal cycles for coastal water levels are caused by a combination of the effects of the average seasonal cycles of air pressure, wind, water temperature, salinity, ocean currents, and river discharge. For many stations, the average seasonal cycle is mainly driven by the steric effect, which is the change in the volume of seawater caused by changes in water density due to temperature and salinity variations. Water levels tend to be highest in late summer/early fall at the end of the heating season and lowest in the late winter/early spring at the end of the cooling season.

Pago Pago and Eastport have essentially no seasonal cycle with no monthly values significantly higher or lower than any other month. The largest seasonal cycles are at Fernandina Beach and Toke Point with a range over 0.3 meters. Philadelphia has continuously high water levels from April to September, caused by a combination of higher river flow in the spring and the steric effect in the summer.

The Atlantic coast stations from South Carolina to northern Florida and the Gulf of Mexico stations from Alabama to Texas have a double-peaked average seasonal cycle. They generally rise from their lowest winter level in January to a secondary peak in May or June, fall to a secondary low in July, before rising to their highest level in September or October. On the Atlantic coast, this modification of the usual steric seasonal cycle has been attributed to the dynamic effect of seasonal variations in the speed of the Gulf Stream (Noble and Gelfenbaum 1992, Blaha 1984). The mass transport of the Florida Current, which connects the Loop Current in the Gulf of Mexico to the Gulf Stream in the Atlantic, is lowest in January and peaks in July (Baringer and Larsen 2001), although it is highly variable from year to year.

The dynamic effect of the California Current has a strong influence on the average seasonal cycles of stations in northern California, Oregon, and Washington which have their lowest levels in spring and summer when the wind-driven southward current is usually strongest, causing the upwelling of cold water along the coast. The seasonal cycles for Alaskan stations also reach their lowest levels in spring or early summer, influenced by variation in the strength of the northwest-flowing Alaska Current.

Traditional tide prediction is accomplished by summing a series of sinusoidal curves at a limited number of frequencies known as the tidal harmonic constituents (Schureman 1958). The constituents are primarily diurnal and semidiurnal, but they also include the solar annual constituent Sa and the solar semiannual constituent Ssa. Although there is a small astronomical tide-producing force at these frequencies, most of the water level variation found by harmonic analysis at these frequencies is the climate-driven average seasonal cycle. As a result, Sa and Ssa are sometimes referred to as meteorological constituents (Center for Operational Oceanographic Products and Services 1999). It is important to include them in tide predictions; without them, observations will appear to be noticeably higher or lower than the predicted tide at various times of the year.

CO-OPS, which is charged with making the official tide predictions for the United States, derives a unique set of tidal constituents classified as “accepted” for each station. For long-term stations, the tidal constituents from as many as five 1-year harmonic analyses are usually averaged to obtain the diurnal and semidiurnal tidal constituents; however, the Sa and the Ssa constituents are usually derived by averaging the results of as many as 19 years (a tidal epoch) of 1-year harmonic analyses. If they are generally consistent in amplitude and phase for each year, they are accepted and included in the set of constituents used for tide prediction. If they are not very consistent from year to year, they are not included in the accepted set of tide constituents for that station. For some shorter-term stations such as Chesapeake City and Redwood City, the Sa and Ssa constituents of a nearby longer-term station have been adopted. The accepted tidal constituents can be found on the CO-OPS website
(http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Harmonic+Constituents)

For this report, the twelve monthly values of the average seasonal cycles in Table B of Appendix III have been used to derive the amplitudes and phases of the Sa and Ssa tidal constituents using the CO-OPS tidal harmonic analysis program (Zervas 1999). The results are listed in Table C of Appendix IV. The values of the accepted tidal constituents that CO-OPS uses to make the official tide predictions are also listed for comparison. The amplitudes and phases of Sa and Ssa are also compared by region in Figures 20 to 25. The values derived for this report are indicated by the filled symbols while the accepted CO-OPS tide constituents are indicated by the unfilled symbols. If CO-OPS has no accepted set of constituents, there are blank spaces in Table C and no symbols are plotted on the figures. If CO-OPS has a set of accepted constituents that doesn’t include Sa or Ssa, there are zeros in Table C and the unfilled symbols on the figures are plotted at zero.

It is apparent from Figures 20 to 25 that for most stations the CO-OPS accepted values for Sa and Ssa closely correspond with the values derived from the average seasonal cycle which is based on the entire record at each station instead of 19 years or fewer. It is also apparent that the constituents vary smoothly in amplitude and phase from one station to the next along each coastline. The Sa amplitude is usually larger than the Ssa amplitude. The exceptions are at Eastport, Port Chicago, and at all the stations in Texas where Ssa is stronger than Sa.

At some stations, the weaker Ssa constituent has been zeroed out while only the stronger Sa constituent is used in CO-OPS tide predictions. Comparisons with derived values at neighboring stations indicate that the Ssa amplitudes and phases are highly consistent along a coastline and Ssa values could be used in the predictions. At Wilmington and Port Chicago, the Sa constituent is zeroed out while only the Ssa constituent is used in the official tide predictions.

At Bar Harbor, Ocean City, Southport, Eugene Island, Garibaldi, Mokuoloe, Guam, Pago Pago, and Kwajalein, both Sa and Ssa are set to zero in the accepted set of constituents, so no seasonal cycles are used in the CO-OPS tide predictions. Guam, Pago Pago, and Kwajalein are strongly influenced by the interannual ENSO forcing. Therefore, any Sa or Ssa obtained by harmonic analysis of a year affected by a strong El Niño or La Niña event will be very different from those obtained by harmonic analysis of ENSO-neutral years. However, tide predictions without Sa or Ssa will not reflect the seasonal cycle even in ENSO-neutral years.

Although at most stations the accepted constituents compare very well with the constituents derived from the average seasonal cycles, there are some differences. At Montauk and Philadelphia, the accepted Sa and Ssa amplitudes appear to be twice the amplitudes derived from the average seasonal cycle. At Anchorage, the accepted Ssa amplitude is greater than the Sa amplitude which doesn’t correspond with its average seasonal cycle or with the Ssa amplitude at any of the other Alaskan stations. At Newport and Fernandina Beach, there appears to be a problem with the accepted phase of Sa. It is recommended that CO-OPS investigate these discrepancies and update the constituents as necessary.

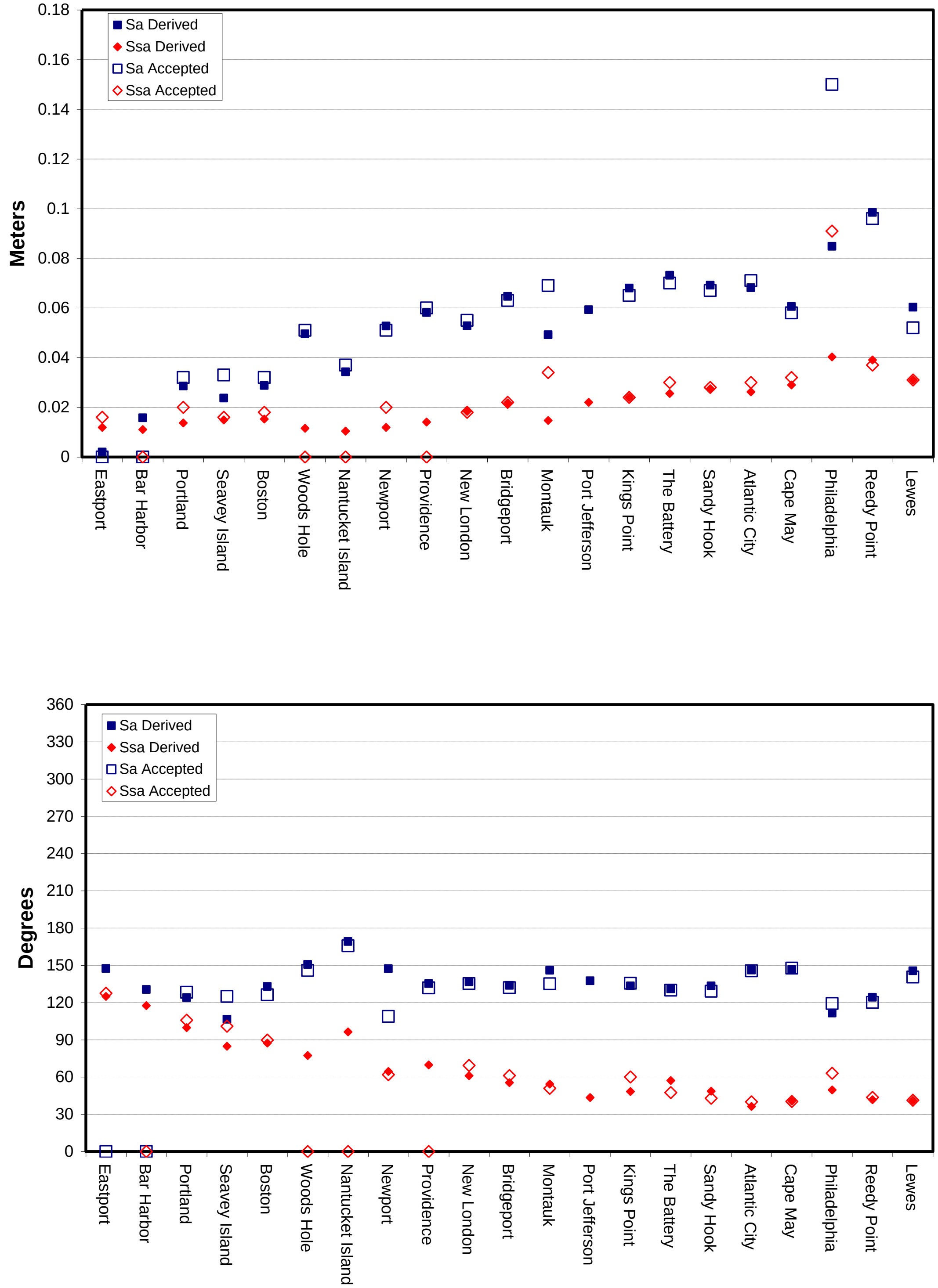
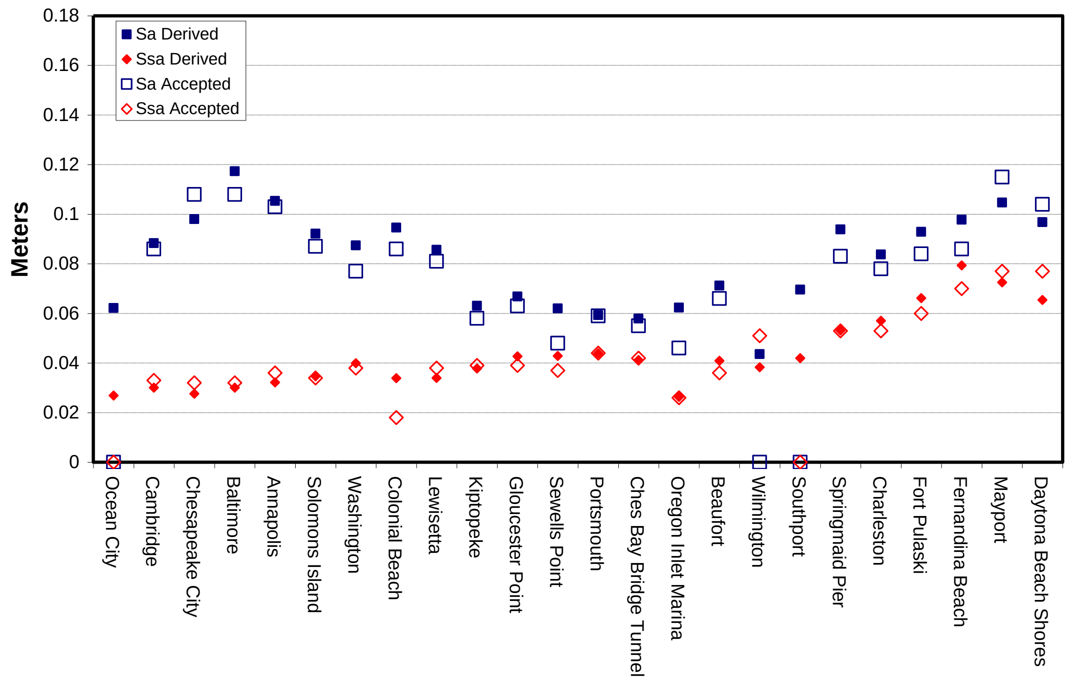


Figure 20. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for northern U.S. east coast stations.



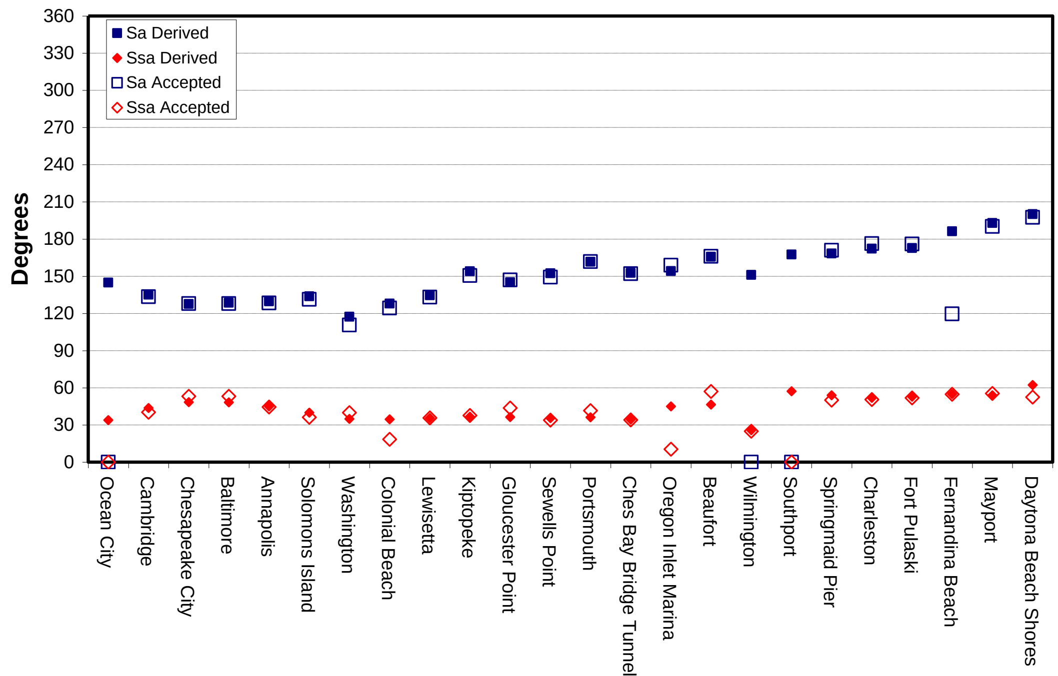


Figure 21. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for southern U.S. east coast stations.

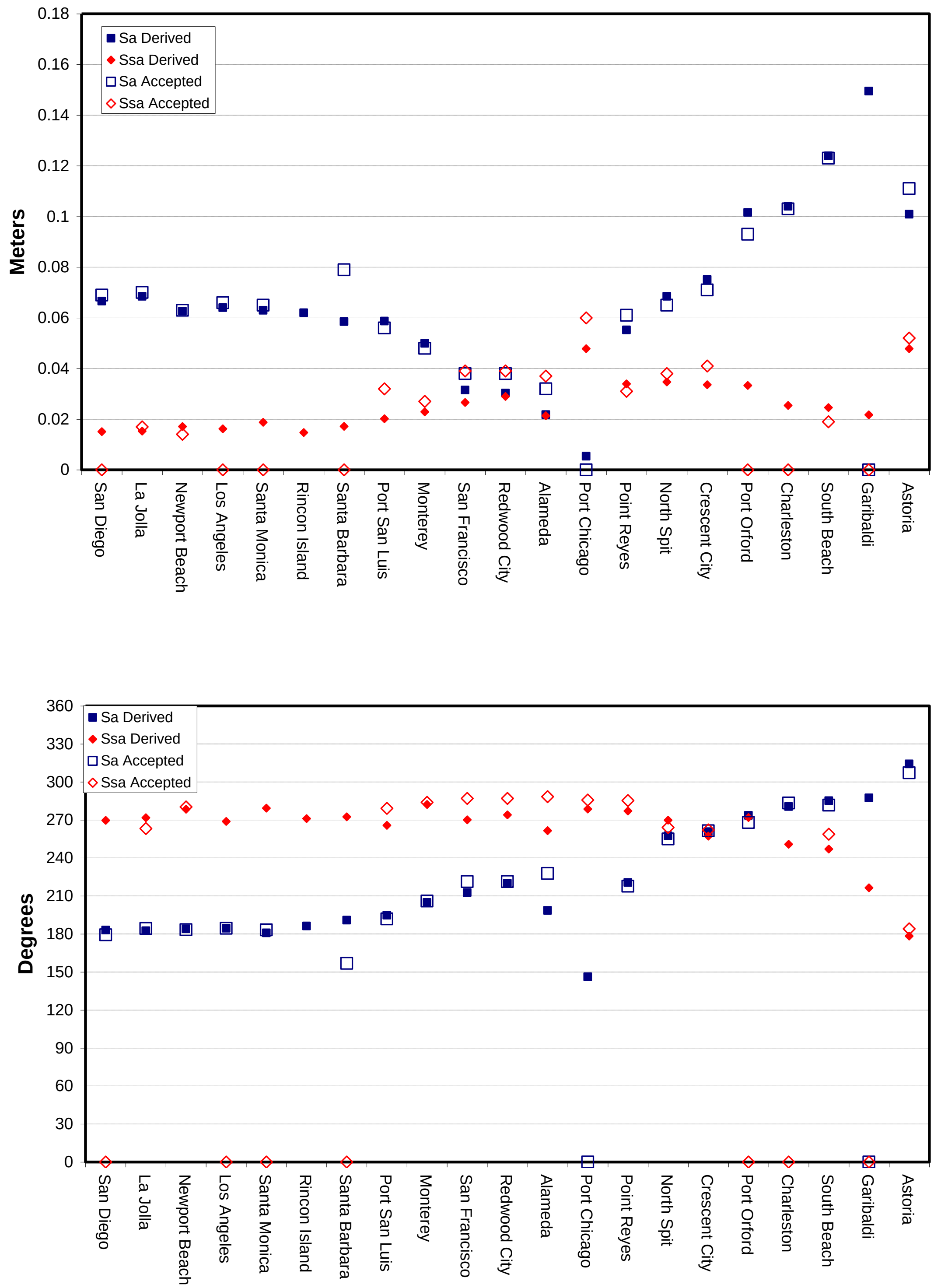
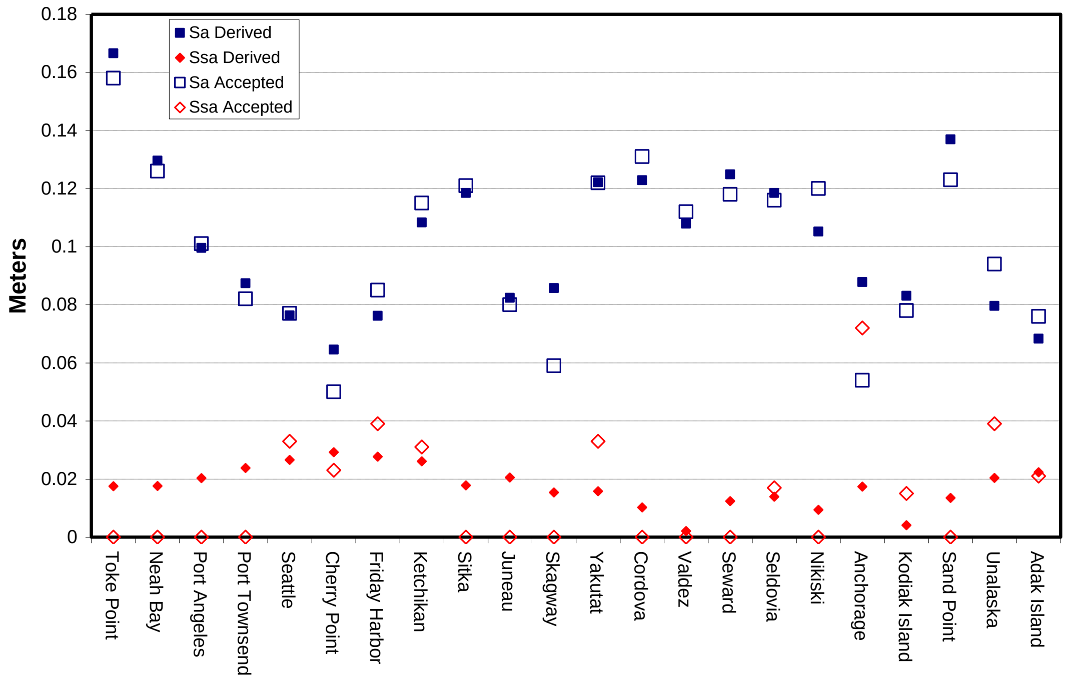


Figure 22. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for southern U.S. west coast stations.



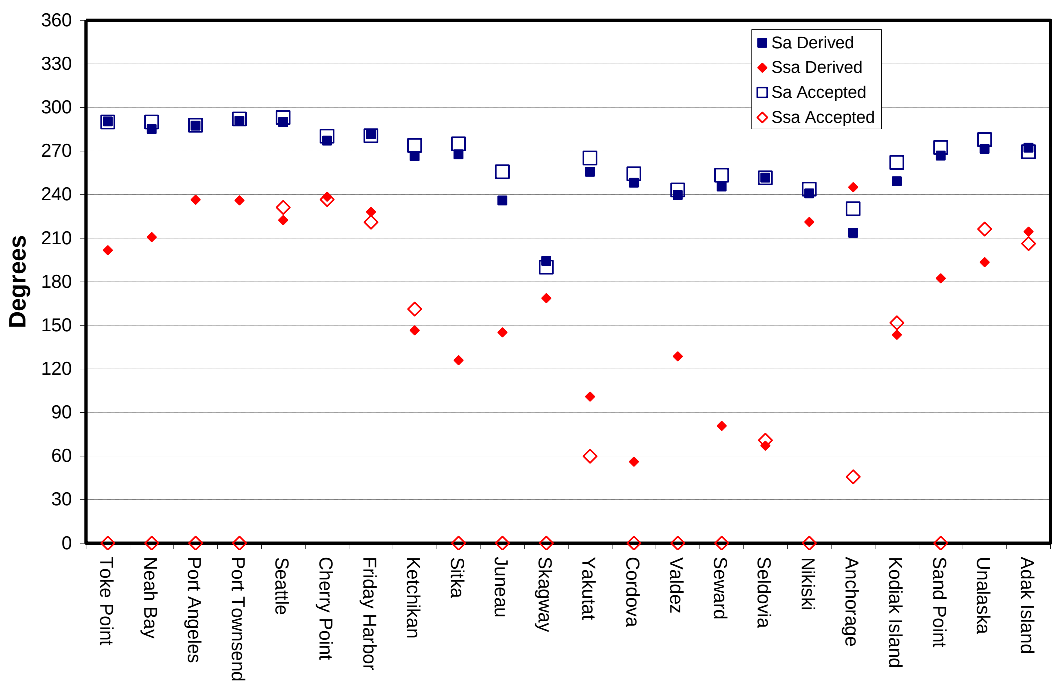
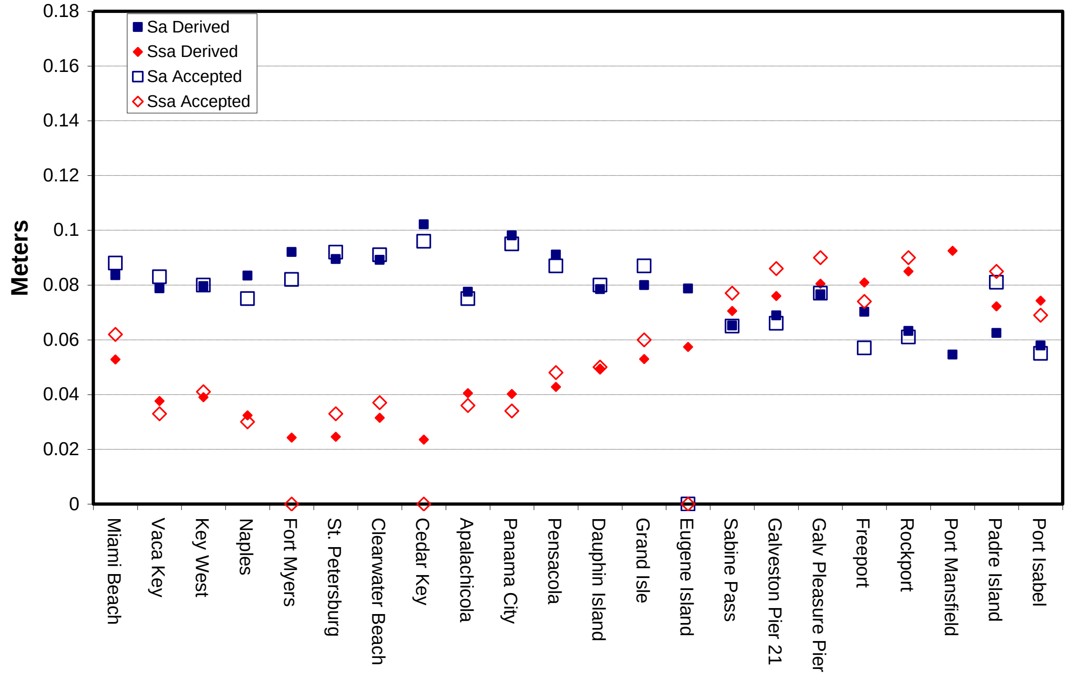


Figure 23. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for northern U.S. west coast and Alaska stations.



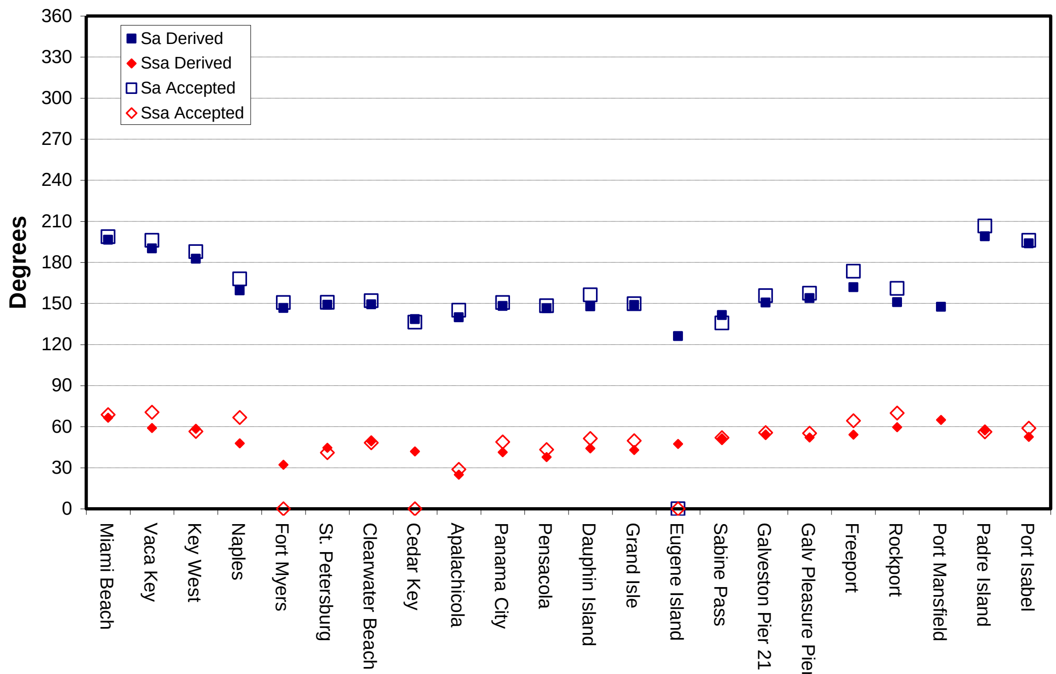
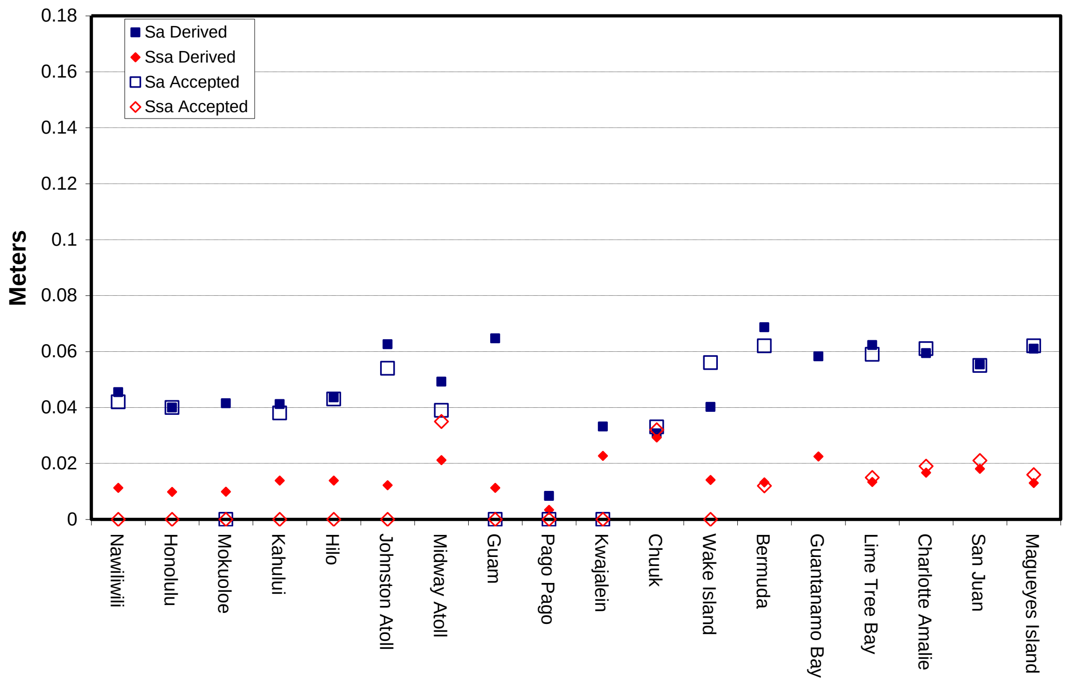


Figure 24. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for Gulf of Mexico stations.



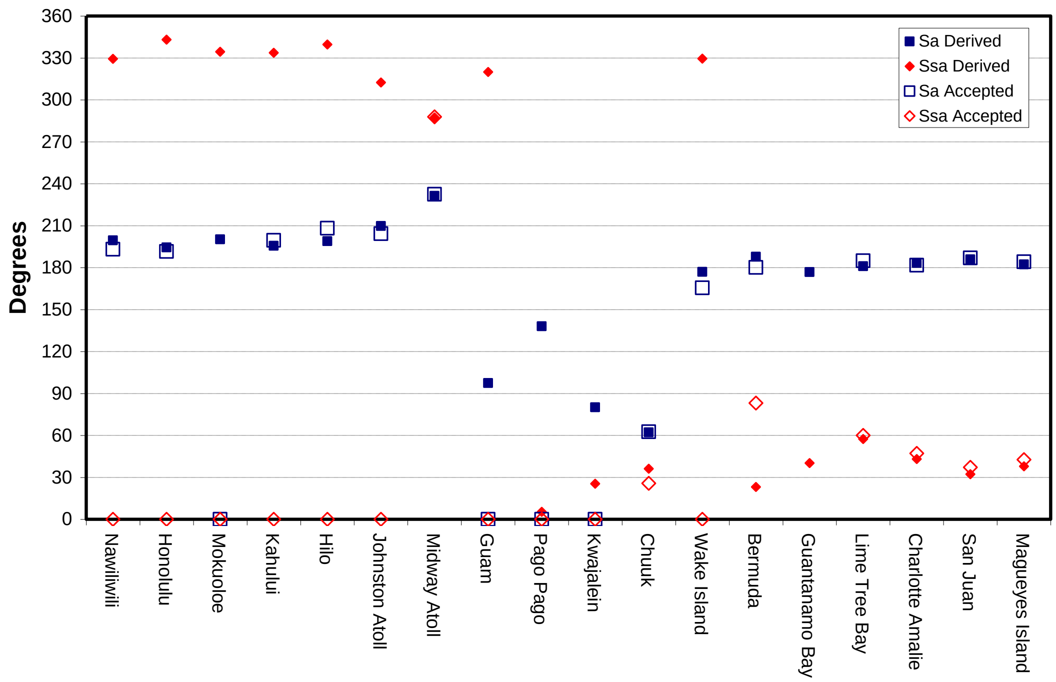


Figure 25. Comparison of derived and accepted long-term tidal constituent amplitudes (top) and phases (bottom) for tropical Pacific, Bermuda, and Caribbean stations.

VARIABILITY OF RESIDUAL MONTHLY MEAN SEA LEVEL

When the calculated linear trend and the average seasonal cycle are removed from the MSL series, the residual series represents the interannual MSL variability. Periods of large positive or negative residuals indicate anomalous conditions in the coastal ocean caused by variations in water temperature, salinity, winds, air pressure, currents, or river discharge. The residuals are highly correlated from one station to the next along the coastline. When the residuals at each station were compared with the residuals at neighboring stations, a few periods of suspect data were discovered when there is a noticeable offset of 0.1-0.2 m for periods of 4 to 30 months. The periods of suspect data are listed in Table 5. Because these short periods of data have a minimal effect on the calculated linear trends, they were not removed from the time series.

Table 5. Periods of suspect data

Station	Number	Period	Estimated Offset (m)
Ocean City	8570283	6/81-12/83	-0.10
Springmaid Pier	8661000	7/71-12/71	0.15
Daytona Beach Shores	8721120	6/67-6/68	-0.15
Sabine Pass	8770590	1/74-8/74	0.10
Galveston Pleasure Pier	8771510	1/67-6/67	0.10
Galveston Pleasure Pier	8771510	12/70-4/72	0.10
Padre Island	8779750	7/99-4/00	0.10
Santa Monica	9410840	8/83-6/85	-0.10
Santa Monica	9410840	1/92-4/92	0.10
Port San Luis	9412110	1/69-1/70	0.10
Astoria	9439040	6/48-5/49	0.20
Ketchikan	9450460	6/66-9/68	0.10
Skagway	9452400	10/69-3/70	0.20
Skagway	9452400	1/82-12/82	-0.10
Seldovia	9455500	8/77-6/78	0.20

The primary driver of anomalously high or low water levels in the Pacific Ocean is the El Niño Southern Oscillation (ENSO). During normal periods, easterly equatorial winds maintain higher water levels in the western Pacific. Occasionally, the winds weaken every 3-5 years on a non-periodic basis, resulting in lower water levels in the western Pacific and higher water levels and higher ocean temperatures in the central and eastern equatorial Pacific. These anomalies then propagate to the north and south along the western coastlines of North and South America. An opposite condition called La Niña occurs when the easterly equatorial winds are stronger than normal leading to unusually high water levels in the western Pacific and low water levels and temperatures in the central and eastern equatorial Pacific. During stronger ENSO events, the effects are not confined to the Pacific basin but can propagate throughout the world via atmospheric teleconnections.

The high correlation between ENSO and coastal water levels in the Pacific are demonstrated in Figures 26 and 27. The Oceanic Niño Index (ONI) has become the standard method that NOAA's Climate Prediction Center uses in defining ENSO episodes (Climate Prediction Center 1999). It is based on a 3-month running mean of sea surface temperature in degrees in the Niño 3.4 region (5°N-5°S, 120°W-170°W) relative to a 1971-2000 base period. It has been divided by a factor of 10 in Figures 26-27 for comparison with the water level residuals.

San Diego and most U.S. west coast and Alaska stations are highly correlated with the ONI. Kwajalein in the western equatorial Pacific Ocean is also highly correlated with the ONI, but has an opposite sign; when the ONI is high, Kwajalein has low water levels and when the ONI is low, Kwajalein has high water levels. The Pacific island stations at Guam, Pago Pago, and Chuuk are also inversely correlated with the ONI. In contrast, the Hawaiian stations, Johnston Atoll, Midway Atoll, and Wake Island are not correlated with the ONI.

Since residual MSLs are highly correlated from station to station along a coastline, they represent regional anomalous conditions in the coastal ocean. In order to highlight extremes in coastal ocean conditions and to determine the geographical extent of such events, an anomaly threshold of 0.1 m was applied to the 5-month average of the monthly MSL residuals (Zervas 2001). A positive anomaly was defined to occur when the 5-month average is above 0.1 m; a negative anomaly was defined to occur when the 5-month average is below -0.1 m.

The number of months each year with extreme residual MSLs are listed in Table 6 for the Atlantic stations and Table 7 for the Pacific stations. The years with monthly residuals above 0.1 m are positive and are shaded red. The years with monthly residuals below -0.1 m are negative and are shaded blue. Years with no extreme monthly residuals are indicated by a zero. Years without data are blank. The periods of suspect data in Table 5 are not included in Tables 6 and 7. Tables 6 and 7 indicate the time periods and the regional extent of MSL anomalies for the past 100 years.

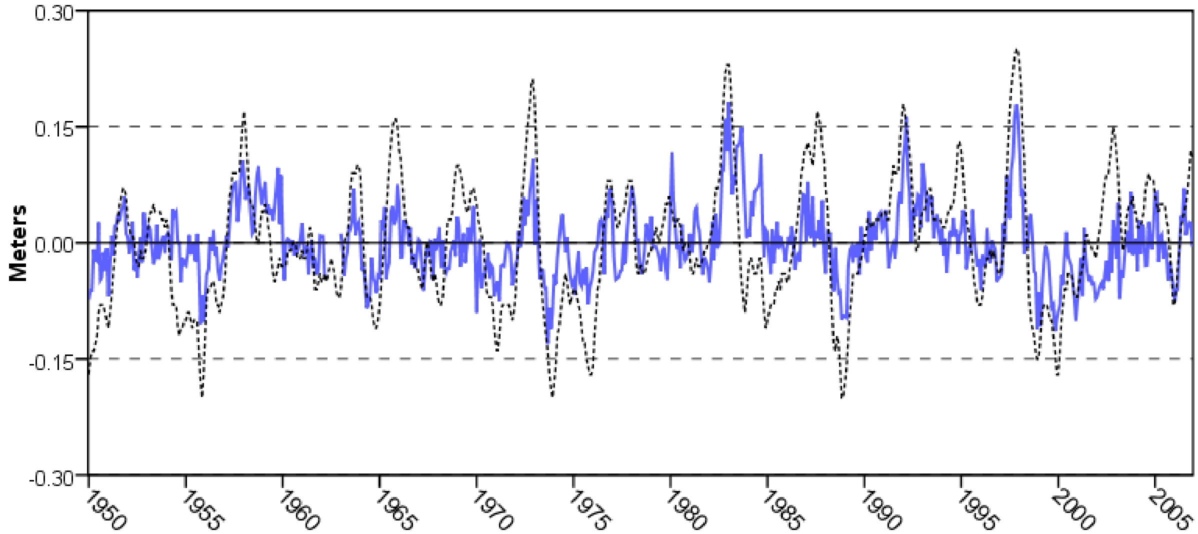


Figure 26. Comparison between the monthly mean sea level residual for San Diego (solid line) and the Oceanic Niño Index (dashed line). The ONI has been divided by a factor of 10 to show the correlation; its units are in degrees.

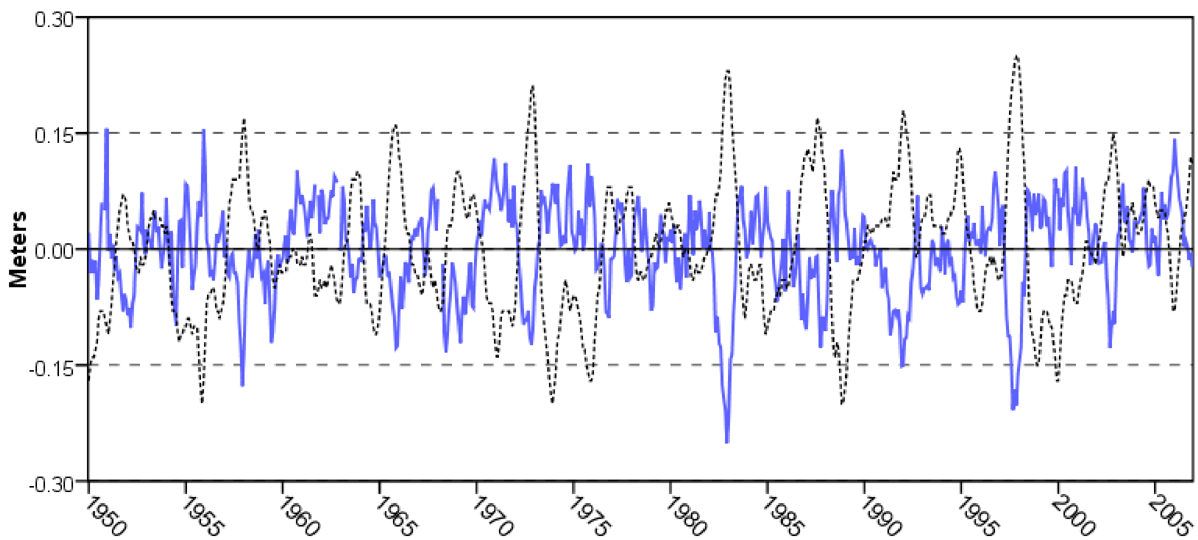


Figure 27. Comparison between the monthly mean sea level residual for Kwajalein (solid line) and the Oceanic Niño Index (dashed line). The ONI has been divided by a factor of 10 to show the correlation; its units are in degrees.

The earliest definable regional anomalies on the U.S. east coast (Table 6) appear to be low anomalies in 1931 from Charleston to Galveston. In 1947-1948, a period of high anomalies occurred from Wilmington to Grand Isle, followed in 1949-1950 with high anomalies from Grand Isle to Port Isabel. High anomalies occurred along the east coast from New London to

Mayport and in the northern Gulf of Mexico in 1972-1973. There was a strong El Niño event taking place in the equatorial Pacific at that time; however there were no concurrent positive anomalies on the U.S. west coast. High anomalies also occurred in 1975 from Pensacola to Padre Island.

Very low anomalies were observed on the east coast in 1976-1977 from Providence to Beaufort followed by another period of low anomalies in 1980-1981 from the Battery to Mayport. During the extreme El Niño of 1982-1983, there were high anomalies from Kiptopeke to Fernandina Beach. During another extreme El Niño in 1997-1998, the east coast from Providence to Wilmington experienced a period of high anomalies. Since 2000, the only regional anomalies were in 2005-2006 from Grand Isle to Galveston.

The earliest definable regional anomalies on the U.S. west coast (Table 7) were the low anomalies that appeared in 1929-1930 from Astoria to Ketchikan. The strong El Niño of 1940-1941 resulted in high anomalies in California and in southeast Alaska. With the establishment of the Pacific stations at Guam, Pago Pago, Kwajalein, and Chuuk in the late 1940s, their inverse correlation with extreme events on the U.S. west coast becomes apparent. The El Niño of 1957-1958 caused high anomalies from San Francisco to Ketchikan in 1958.

The extreme El Niño event of 1982-1983 caused low anomalies at Guam, Pago Pago, Kwajalein, and Chuuk and high anomalies along the entire U.S west coast from San Diego to Unalaska. Low anomalies occurred in 1985 from Oregon to Alaska and high anomalies in 1987-1988 in Alaska. The strong La Niña event in 1988-1989 resulted in high anomalies at Guam and Chuuk and low anomalies from California to Alaska.

Another El Niño event in 1992 resulted in high anomalies in California and Alaska. The extreme El Niño of 1997-1998 caused low anomalies at Guam, Pago Pago, and Kwajalein and high anomalies along the entire U.S. west coast from San Diego to Adak Island. Recently, stations in Oregon and Washington experienced low anomalies in 2000-2001 followed by low anomalies in Alaska in 2002.

Table 6. Number of months with extreme residual water levels for Atlantic stations.

Station	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Bermuda																									
Eastport																							0	0	0
Bar Harbor																									
Portland						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seavey Island																				0	0	0	0	0	0
Boston															0	0	0	0	0	0	0	0	0	0	0
Woods Hole																									
Nantucket Island																									
Newport																								0	0
Providence																									
New London																									
Bridgeport																									
Montauk																									
Port Jefferson																									
Kings Point																									0
The Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0
Sandy Hook																									
Atlantic City					0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0
Cape May																									
Philadelphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1	-1	0	-1	0
Reedy Point																									
Lewes													0	0	0	0	0								
Cambridge																									
Baltimore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annapolis																						0	0	0	0
Solomons Island																									
Washington																			0	0					0
Kiptopeke																									
Gloucester Point																									
Sewells Point																						0	0	0	0
Portsmouth																									
Beaufort																									
Wilmington																									
Springmaid Pier																									
Charleston															0	0	0	0	0	0	0	0	0	0	-4
Fort Pulaski																									
Fernandina Beach	-2	2	0	0	0	0	0	0	0	0	-4	0	0	0	0	0	0	0							
Mayport																						0	0	0	-4
Daytona Bch Shores																			0	0	0	0	0	0	-1
Miami Beach																									0
Vaca Key																									
Key West							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naples																									
Fort Myers																									
St Petersburg																									
Clearwater Beach																									
Cedar Key								0	0	0	0	0	0	0	0	0	0	0	0						
Apalachicola																									
Panama City																									
Pensacola																	0	0	0	0	0	0	0	0	-3
Dauphin Island																									
Grand Isle																									
Sabine Pass																									
Galveston Pier 21		2	0	-1	0	0	1	0	0	0	-4	-1	1	0	6	0	2	0	0	-1	0	0	2	0	-7
Galv Pleasure Pier																									
Freeport																									
Rockport																									
Port Mansfield																									
Padre Island																									
Port Isabel																									

Table 6. Number of months with extreme residual water levels for Atlantic stations.

Station	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Bermuda		0	0	0	0	0			0	0	0		0	-1	-3	0	0	0	0	0	0	0	0	4	1
Eastport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bar Harbor																0	0	0	0	0	0	0	0	0	0
Portland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seavey Island	0	0	0						0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boston	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Woods Hole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nantucket Island																									
Newport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Providence								0	0	0	0	0	0	0	0	0									0
New London							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bridgeport																									
Montauk																0	0	0	0	0	0	0	0	0	0
Port Jefferson																									
Kings Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sandy Hook		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atlantic City	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape May																									
Philadelphia	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0
Reedy Point																									0
Lewes					0	0	0	0								0	0	0			0	0	0	0	0
Cambridge												0	0	0	0	0	0	0	0	0					
Baltimore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annapolis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solomons Island							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Washington	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	-1	0	0	0	0	0	0
Kiptopeke																				0	0	0	0	0	0
Gloucester Point																			0	0	0	0	0	0	0
Sewells Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portsmouth				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaufort																						0	0	0	0
Wilmington				0	0	1	0	0	0	-3	0	0	0	4	0	3	5	0	0	0	0	0	0	1	0
Springmaid Pier																									
Charleston	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0	0	0	0	0	0
Fort Pulaski				0	0	0	0	0	0	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0	0
Fernandina Bch								0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0
Mayport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	0	0	0	0	0	0	0	0
Daytona Bch Shores	0						0	0	0	0	0	0	0	0	0	3	6	0	0						
Miami Beach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	0	0				0	0
Vaca Key																									
Key West	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
Naples																									
Fort Myers																									
St Petersburg																0	4	0	0	0	0	0	0	0	0
Clearwater Beach																									
Cedar Key							0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0
Apalachicola																									
Panama City																									
Pensacola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Dauphin Island																									
Grand Isle																0	2	1	1	0	0	0	0	0	0
Sabine Pass																									
Galveston Pier 21	0	0	0	0	0	0	0	-2	-6	0	0	0	0	1	3	0	0	2	3	0	0	0	0	0	0
Galv Pleasure Pier																									
Freeport																							-3	-1	0
Rockport																	0	2	3	0	0	0	0		
Port Mansfield																									
Padre Island																									
Port Isabel												0	0	3	0	1	0	1	0	0	0	0	0	0	0

Table 6. Number of months with extreme residual water levels for Atlantic stations.

Station	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Bermuda	4	2	0	0	2	5	0	0	0	0	0	0	-1	-6	-3	0	-2	3	3	1	0	0	0	0	0
Eastport	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0		0		0	0	0
Bar Harbor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0			0	0	0	0
Portland	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0
Seavey Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boston	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Woods Hole	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0
Nantucket Island									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Newport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Providence	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	-1	-2	0	0	0	0
New London	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		0	0	-1	0
Bridgeport									0		0	0	0	0	0	0	2	0	0	-2	-2	0	0	0	0
Montauk	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0
Port Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	-2	0	0	0	0
Kings Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	-2	-2	0	0	0	0
The Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-2	-3	0	0	-2	-1
Sandy Hook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	-2	-3	0	0	0	0
Atlantic City	0	0	0	0	0	0	0	0	0	0	0	0	0		0	1	3	0	0	0	-1	0	0	-2	-1
Cape May										0	0	0				1	3	0	0	0		0	0	0	0
Philadelphia	0	0	0		0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	-2	-3	0	0	-3	-2
Reedy Point	-1	0	0	4	0	0	0	0	0														0	-2	-3
Lewes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	-2	-4	0	0	0	0
Cambridge															0	0	2	0	0	0		0	0	0	0
Baltimore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	-2	-3	0	0	-2	0
Annapolis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		-2	0	0	0	0
Solomons Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		-2	0	0	-2	-2
Washington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	0	0	-1	-4	0	0	-2	-5
Kiptopeke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-2	-4	0	0	0	0
Gloucester Point	0	0	0	0	0	0	0	0	0	0	0	0		0	0	1	2	0	0	-2	-4	0	0	-1	-1
Sewells Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	-2	-4	0	0	-2	-1
Portsmouth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	-2	-4	0	0	-1	-1
Beaufort	0	0	0	0	0				0	0	0	0					0	0	0	-1	-2	0	0	-1	0
Wilmington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	-4	-2
Springmaid Pier	0	0	0	0	0	0	0				0	0	0	0		1	1	0			0	0	0	0	0
Charleston	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
Fort Pulaski	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0	0	0
Fernandina Bch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	-1	0
Mayport	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	-5	0
Daytona Bch Shores										0			0	0	0	1	0	0		0		0	0	0	0
Miami Beach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaca Key															0	0	0	0	0	0	0	0	0	0	0
Key West	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naples									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fort Myers									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St Petersburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clearwater Beach																	0	0	0	0	0	0	0	0	0
Cedar Key	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apalachicola											0	0	0	0		0	4	0		0	0	0	0	0	0
Panama City																	0	0	0	0	0	0	0	0	0
Pensacola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	5	0	0	0	0	0	0
Dauphin Island											0	0	0		0	0	0	0		-1	0	0	0	0	0
Grand Isle	0	0	0	0	0	0	-3	-2	0	0	0	0	0	0	0	0	2	0	5		0	0	0	0	0
Sabine Pass		0	0	0	0	0	-7	-5	-3	0	0	0	0	-1	1	2	2		7	0	0	0			
Galveston Pier 21	0	0	0	0	2	0	-4	-3	0	0	0	0	0	0	-2	0	1	0	5	-1	0	0	3	0	0
Galv Pleasure Pier	0	0	0	0	1	0	-1	-9	0	0		0	0	0			1					0	0	-7	-1
Freeport	0	0	0	0	2	0	0	-1	0	0	0	0	0	0	2	0	0	0	3	-4	0	0	0	0	0
Rockport							-1	-4	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	-2	0
Port Mansfield								-1	0	-1	1				2	5	0	0	5	0	0	0	0	-1	0
Padre Island			0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	5	-3	0	0			
Port Isabel	0	0	0	0	1	0	0	-1	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0

Table 6. Number of months with extreme residual water levels for Atlantic stations.

Station	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bermuda	0	-4	0	-2	0	0	-1	0	0	0	0	-3	0	2	0	0	0	0			0	3	0	0	0
Eastport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bar Harbor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0
Portland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seavey Island	0	0	0	0	0															0					
Boston	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Woods Hole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nantucket Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Newport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Providence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
New London	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Bridgeport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Montauk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Port Jefferson	0	0	0	0	0	0	0	0	0	0	0														
Kings Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
The Battery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	0	0
Sandy Hook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Atlantic City	0	1	0	0	0	0	0	0	0	0	0	0	0	-3	0	1	4	0	0	0	0	0	0	0	0
Cape May	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Philadelphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	4	0	0	0	-1	0	4	3	0
Reedy Point	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	0	0
Lewes	0	1	0	0	0	1	0	0	-1	0	0	0	0	0	0	1	4	0	0	0	0	0	0	1	0
Cambridge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Baltimore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	0	0
Annapolis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	-1	-1	0	0	0	0	0	0
Solomons Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	2	0
Washington	0	0	2	0	0	0	0	0	-1	0	0	2	0	0	6	2	5	0	0	0	-5	0		0	0
Kiptopeke	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Gloucester Point	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0			
Sewells Point	0	2	0	0	0	0	-3	0	0	0	0	0	0	0	0	1	5	0	0	0	-1	0	0	1	0
Portsmouth	0	4	0	0	0	0																			
Beaufort	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wilmington	0	4	0	0	0	0	0	0	0	0	0	0	0	1	2	0	4	4	0	0	0	0	0	0	0
Springmaid Pier	1	2	0	0	4	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charleston	0	2	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fort Pulaski	1	2	0	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Fernandina Bch	1	2	0	0	0	2	0	-1	0	2	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Mayport	0	0	0	0	0	0	0	-1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Daytona Bch Shores	0	0																							
Miami Beach																									
Vaca Key	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Key West	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fort Myers	1	4	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
St Petersburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clearwater Beach	0	0	0	0	0	0		0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0
Cedar Key	0	0	0	0	0	-1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apalachicola	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0
Panama City	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pensacola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dauphin Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0
Grand Isle	1	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1
Sabine Pass				0	0	0	0	0	0	4	0	0	0	0	-4	0	0	0	0	0	0	0	0	-1	-4
Galveston Pier 21	1	1	0	0	0	0	0	0	0	3	0	0	0	0	-1	0	0	0	0	0	0	0	0	-1	-4
Galv Pleasure Pier	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1
Freeport	0	1	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rockport	0	0	0	0	0	0	-1	-2	0	0	0	0	0	0	0	0	3	0	0	0	5	0	0	1	0
Port Mansfield	0	0	2	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	0	0	0	0	0	0	0	0
Padre Island		0	0	0	0	0	0	0		0	0	0	0	0	-2	0	0			0	0	0	0	0	0
Port Isabel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Number of months with extreme residual water levels for Pacific stations.

Station	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Nawiliwili																									
Honolulu	0	0	-6	-2	0	0	0	0	2	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Mokuoloe																									
Kahului																									
Hilo																					0	0	0	0	0
Johnston Atoll																									
Midway Atoll																									
Guam																									
Pago Pago																									
Kwajalein																									
Chuuk																									
Wake Island																									
San Diego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La Jolla																			0	0	0	0	0	0	0
Newport Beach																									
Los Angeles																		0	0	0	0	0	0	0	0
Santa Monica																									
Rincon Island																									
Santa Barbara																									
Port San Luis																									
Monterey																									
San Francisco	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Redwood City																									
Alameda																									
Point Reyes																									
Port Chicago																									
North Spit																									
Crescent City																									
Port Orford																									
Charleston																									
South Beach																									
Garibaldi																									
Astoria																			0	0	2	-1	-6	-1	0
Toke Point																									
Neah Bay																									
Port Angeles																									
Port Townsend																									
Seattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	-1	0
Cherry Point																									
Friday Harbor																									
Ketchikan													-1	0	0	0	0	0	0	1	0	0	-2	-1	3
Sitka																		0	0	0					
Juneau																									
Skagway																									
Yakutat																									
Cordova																									
Valdez																									
Seward																			0	5	0	0	0	1	3
Seldovia																									
Nikiski																									
Anchorage																									
Kodiak Island																									
Sand Point																									
Unalaska																									
Adak Island																									

Table 7. Number of months with extreme residual water levels for Pacific stations.

Station	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Nawiliwili																								-1	0
Honolulu	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-3	0
Mokuoloe																									
Kahului																0	0	0		0	0	0	0	-2	0
Hilo	0															0	0	0	0	0	0	0	0	0	0
Johnston Atoll																0			0	0	0	0	0	0	0
Midway Atoll																0	0	0	0	1	0	0	0	0	0
Guam																	0	0	1	0	0	2	3	0	0
Pago Pago																	0	0	0	0	0	0	0	2	
Kwajalein															0	0	0	0	0	0	0	0	0	0	0
Chuuk																			0	0		0	0	3	1
Wake Island																			0	0	1	4	0	0	0
San Diego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La Jolla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Newport Beach																								0	0
Los Angeles	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santa Monica		-1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rincon Island																									
Santa Barbara																									
Port San Luis														0	-1	0	0	0	0	0	0	0	0	0	0
Monterey																									
San Francisco	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Redwood City																									
Alameda								0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Point Reyes																									
Port Chicago																									
North Spit																									
Crescent City		0	0	0	0	0	-1	-2	1	4	0	0	0	0	0	0			0	0	0	0	0	0	0
Port Orford																									
Charleston																									
South Beach																									
Garibaldi																									
Astoria	0	1	0	0	-3	-1	-1	-2	0	0	0	0	-5	-1	0	0			1	0	0	0	0	-1	-2
Toke Point																									
Neah Bay			0	0	-3	-1	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Port Angeles																									
Port Townsend																									
Seattle	0	0	0	0	-2	0	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cherry Point																									
Friday Harbor			0	0	0	0	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ketchikan	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Sitka							0	0	2	1	0	0	0	0	-1	-1	0	0	0	0	0	0	0	0	-2
Juneau					0	0	0	2	2				0	0	-1	-1	0	0	0	0	0	0	0	0	-3
Skagway													0	0	-1	0	0	0	-1	-3	2	2	0	-2	-4
Yakutat									0	0	0	0	0	0	-2	-1	0	0	0	0	0	0	0	-1	-4
Cordova																		0	0	0					
Valdez																									
Seward	0	0	0	0	-1	0	0						0	0	0	0	0	0	0	0	3	2	0	-1	-2
Seldovia																									
Nikiski																									
Anchorage																									
Kodiak Island																			0	0	0	1	0	0	-2
Sand Point																									
Unalaska			0	0	0	-2	0	0							0	0	0	0	0	0	2	3	0	0	0
Adak Island												0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Number of months with extreme residual water levels for Pacific stations.

Station	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Nawiliwili	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Honolulu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokuoloe	0	0	0	0	0	0	0	0	0	0	0	0	0					0							0
Kahului	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Hilo	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Johnston Atoll	1	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-1	-2	0	0
Midway Atoll	0	0	0	0	0	0	0	2	0	0	0	0	-2	0	0	0		0	-1	0	0	-2	0	0	-3
Guam	0	0	-1	0	0	0	0	0	0	0	-1	-3	-2	5	6	-7	0	1	0		0	0	0	0	4
Pago Pago	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	-1	0	0	0
Kwajalein	-2	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0
Chuuk	-3	-2	0	0	0	0	-1	0	-4	-1	0	0	0	0	1	-7	2	0	1	0	0	0	0	0	0
Wake Island	0	0	0	1	0	0	0	0	0	-2	0		0	0	0	0	0		0	0	0		0	0	0
San Diego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La Jolla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Newport Beach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santa Monica	0	1	0	0	0	0	0	0	0									0	0	0	0	0	0	0	0
Rincon Island						0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0
Santa Barbara																		0	0	0	0	0	0	0	
Port San Luis	0	0	0		0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	0	0
Monterey																		0	0	0	0	0	0	0	0
San Francisco	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-3	0	0	0	0
Redwood City																			0	0					
Alameda	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	-2	-2	0	0	0	0
Point Reyes																			0	-1	0	0	0	0	0
Port Chicago																					-4	0	0	0	0
North Spit																						0	0	0	0
Crescent City	1	4	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	0	-2	0	1	0	0	0
Port Orford																						1	0		
Charleston														0	0	0	0	0	0	0	1	2	0	0	0
South Beach											0	1	0	0	0	0	0	0	0	0	-3	0	0	0	0
Garibaldi														0	0	0	0	0	0	-1	-2	0	0	0	
Astoria	-1	2	0	0	-2	-1	0	-2	0	0	0	1	1	-2	0	2	-4	2	0	-1	-6	-2	-1	0	0
Toke Point																	0				0	-2	-1	0	0
Neah Bay	0	3	0	0	-1	0	0	-1	2	1	0	1	0	0	0	0	0	0	0		0	0	0	0	0
Port Angeles																			0	0	0	0	0	0	0
Port Townsend																0	0	0	0	0	-1	0	0	0	0
Seattle	0	1	0	0	0	0	0	-1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cherry Point																	0	0	0	0	0	0	0	0	0
Friday Harbor	0	3	0	0	-2	-3		-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ketchikan	-2	1	0	0	0	0	1	0	-1	0			1	0	0	0		0	0		0	0	0	0	0
Sitka	-3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juneau	-3	0	0	0	0	0	3	0	0	0	0	0	0	-2	-3	-1	0	0	0	4	0	0	0	0	0
Skagway	-2	0	0	1	0	-2	0		0	1	0	0													
Yakutat	-3	0	0	0	0	-4	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	1	0
Cordova								0	-3	0	-1			0	0	0	0	0	0	0	0	0	0	0	0
Valdez																		0	-1	0	0	-1	-2	0	0
Seward		0	0		0	0	1	0	0	0	-3	0	0	-1	-2	-3	0				0	0	0	0	0
Seldovia								0		0	0	0	0		-3	-5	-1	0	0	4	4		0	0	0
Nikiski																	0							0	0
Anchorage																-3	-2	-1	0	2				0	
Kodiak Island	0	0	0	0	-2	-2	0	0											0	0					
Sand Point																	-1	0	0	2	0	0	0	0	1
Unalaska	1	3	2	1	0	0	0	0	0	0	0	0	1	2	-2	-3	-1	0	0	0	0		0	0	1
Adak Island	2	1	0	0		-1	0		0	0	0	0	0	0	0	0	0	0	0				0	0	0

Table 7. Number of months with extreme residual water levels for Pacific stations.

Station	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Nawiliwili	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Honolulu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokuoloe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kahului	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hilo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0
Johnston Atoll	0	0	0	0	0	0	5	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0				
Midway Atoll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0
Guam	-4	-6	9	2	0	-2	4	3	0	0	0	0	0	-1	0	-8	-7	3	0	0	-3	-2	-1	-2	0
Pago Pago	0	-9	0	0	0	-3	0	0	0	0	0	0	0	0	0	0	-11	0	0	0	0	0	0	0	0
Kwajalein	-6	-3	0	0	0	0	0	0	0	-2	-3	0	0	0	0	-6	-2	0	0	0	0	0	0	1	2
Chuuk	-7	-2	0	2	0	-2	5	2	0				-4	0											
Wake Island	0	0	6	0	-1	0	0	-2	0	0	-2	0	0	0	0	0	0	0	3	0	0	0	1	-1	-1
San Diego	3	7	0	0	0	0	0	0	0	0	3	0	0	0	0	4	1	0	0	0	0	0	0	0	0
La Jolla	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	5	1	0	0	0	0	0	0	0	0
Newport Beach	2	5	0	0	0	0	-2	-1	0	0	0	0													
Los Angeles	2	3	0	0	0	0	-1	0	0	0	2	0	0	0	0	4	1	0	0	0	0	0	0	0	0
Santa Monica	1				0	0	-1	-1	0			0	0	0	0	4	1	0	0	0	0	0	0	0	0
Rincon Island	2	7	0	0	0	0	0	0	0																
Santa Barbara										0	0	0	0	0	0	2								-1	-2
Port San Luis	2	4	0	0	0	0	0	0	0	0	2	0	0	0	0	4	1	0	0	0	0	0	0	0	0
Monterey	2	9	0	0	0	0	0	0	0	0	3	0	0	0	0	3	2	0	0	0	0	0	0	0	0
San Francisco	3	11	0	0	0	0	-1	-1	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0
Redwood City		1	0													1	4	0	0	0	0	0	0	0	0
Alameda	3	11	0	0	0	0	-1	-2	0	0	0	0	0	1	0	4	4	0	0	0	0	0	0	0	0
Point Reyes	2	10	0	0	0	0	-2	-2	0	0	3	0	0	0	0	3	3	0	0	0	0	0	0	0	0
Port Chicago	5	12	0	0	0	0	-5	-3	-4	-1	0	0	0	4	0	2	5	0	-1	-2	-2	0	0	0	5
North Spit	2	5	0	0	0	0	-1	-1	0	0	1	0	0	0	0	4	4	0	0	0	0	0	0	0	0
Crescent City	2	7	0	0	0	0	-2	-1	0	0	4	2	0	0	0	3	3	0	0	0	0	0	0	0	0
Port Orford	3	7	0	-3	0	0	-3	-3	-3	0	1	0	0	0	0	4	3	0			0	0	0	0	0
Charleston	3	4	0	-1	0	0	-1	0	-1	0	0	0	0	1	0	4	3	0	0	-1	0	0	0	0	0
South Beach	2	6	0	-2	0	0	-1	0	0	0	0	4	0	0	0	6	3	0	-1	-3	0	0	0	0	0
Garibaldi																								0	0
Astoria	4	6	0	-1	0	0	0	0	0	0	0	0	0	1	3	10	3	1	-1	-7	0	0	0	0	0
Toke Point	3	6	0	-2	0	0	-1	-1	0	0	0	2	0	0	0	6	3	1	-1	-2	0	0	0	0	0
Neah Bay	2	6	0	-2	0	0	-1	0	0	0	0	0	0	0	0	6	3	0	-1	-2	0	0	0	0	0
Port Angeles	2	5	0	-2	0	0	-1	0	0	0	0	1	0	0	0	6	3	0	0	-2	0	0	0	0	0
Port Townsend	2	6	0	-2	0	0	0	0	0	0	0	0	0	0	0	5	3	0	0	-1	0	0	0	0	0
Seattle	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0	0	-2	0	0	0	0	0
Cherry Point	3	6	0	0	0	0	-1	0	0	0	1	0	0	0	0	5	3	0	-1	-2	0	0	0	0	0
Friday Harbor	3	5	0	0	0	0	-1	0	0	0	0	0	0	0	0	5	3	0	-1	-2	0	0	0	0	0
Ketchikan	1	5	0	-1	0	0	0	0	0	1	3	-1	0	0	0	3	2	0	0	0	-3	0	0	0	0
Sitka	0	3	0	-2	0	0	0	-1	0	0	3	0	0	0	0	2	3	0	0	0	0	0	0	0	0
Juneau	1	4	1	-2	0	1	0	0	0	1	4	0	0	0	-1	1	2	0	0	0	-4	0	0	0	0
Skagway		1	2	-2	1	6	5	0	0	1	4	0	0	-3	-2	1	2	0	0	0	-2	0	0	0	-1
Yakutat	2	5	2	0	0	6	0	-1	0	0	3	-2	0	0	0	1	1	0	0	0	-5	0	-2	-2	-1
Cordova	1	3	1	-1	0	3	2	0	0	1	3	0	0	0	0	2	2	0	0	0	-3	0	0	0	0
Valdez	0	2	0	-2	0	5	5	0	0	1	3	0	0	0	0	2	2	0	0	0	-3	0	0	0	0
Seward	1	3	0	-2	1	4	5	-1	-1	0	3	0	0	0	-2	1	2	0	0	0	-3	0	0	0	0
Seldovia	0	3	0	-2	0	4	0	-4	-2	-2	2	0	0	0	0	1	3	0	0	0	-1	1	0	0	0
Nikiski	0														-1	1	2	0	0	0	-3	0	0	0	0
Anchorage		0	2	0	1	4	4	0	0	2	4	3	0	0	0	1	2	0	0	0	-4	0	0	0	0
Kodiak Island	0	2	0	0	0	0	0	-4	-2	-1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
Sand Point	1	4	0	-1	0	3	-1	-4	-2	-1	0	0	0	0	0	1	2	0	0	0	1	1	1	0	0
Unalaska	0	4	0	0	0	0	0	-1	-1	-1	0	0	0	0	0	1	3	0	0	0	2	1	0	0	0
Adak Island	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

DISCUSSION

Linear MSL trends have been calculated for all NWLON stations that have a data range of over 30 years. They have a wide range of confidence intervals primarily determined by the length of data. In Figure 28, the +/- 95% confidence intervals of the trends are plotted versus the year range of data. Seven of the stations which have large data gaps are not included in the plot since they have slightly larger error bars than the stations with nearly complete data records. The seven stations, which have less than 50% data availability between their first and last years, are Chesapeake City, Oregon Inlet Marina, Southport, Santa Barbara, Redwood City, Garibaldi, and Nikiski, although trends with reasonable error bars were obtained for these stations because of their year range of data (Table 4).

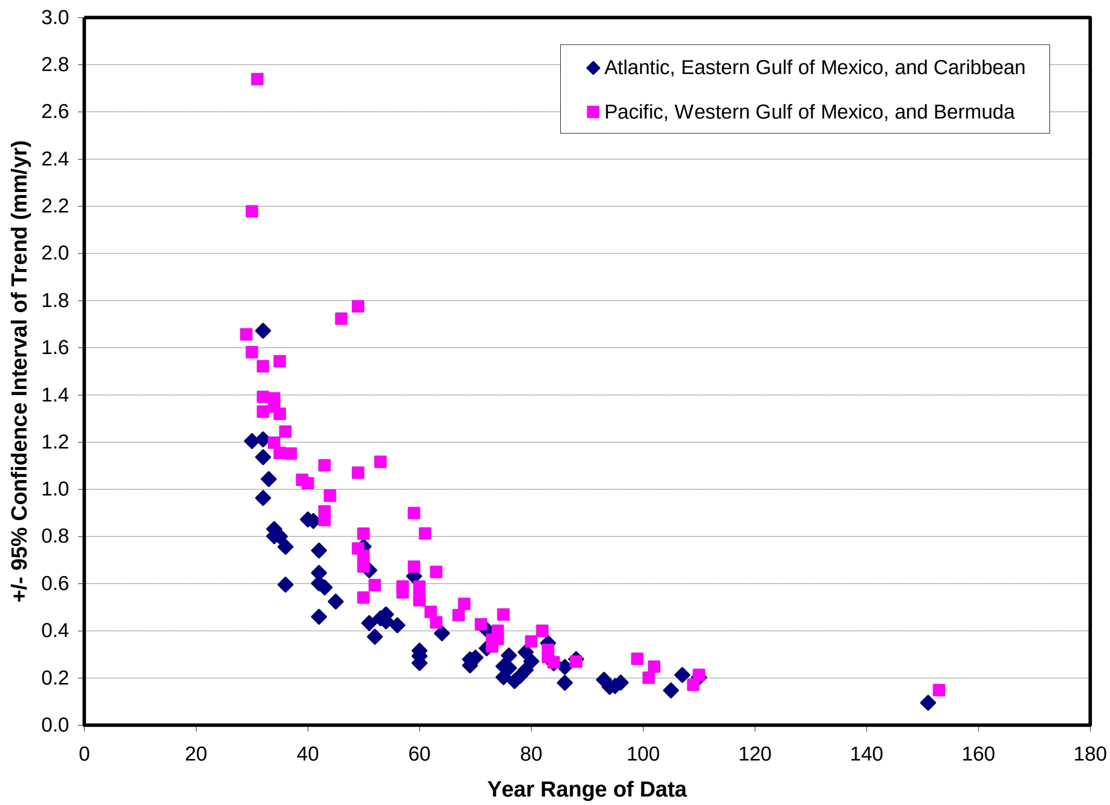


Figure 28. +/- 95% confidence interval of linear MSL trends (mm/yr) versus year range of data.

When Figure 28 is transformed into a log-log plot (Figure 29), it is apparent that there is an inverse power relationship between the +/- 95% confidence interval and the year range of data. The best fit regression line is

$$y = 395.5\, x^{-1.643} \tag{8}$$

where y is the +/- 95% confidence interval and x is the year range of data. There are three outliers. Guam and Chuuk have nearly 50 years of data but their 95% confidence intervals are equivalent to those that might be achieved with only 25 years of data elsewhere. This is because of the large amplitude of the ENSO events in the western Pacific. Port Chicago, in Suisun Bay, is the station with the widest error bars and is occasionally influenced by river discharge which results in enhanced water levels during ENSO events (Ryan and Noble 2007).

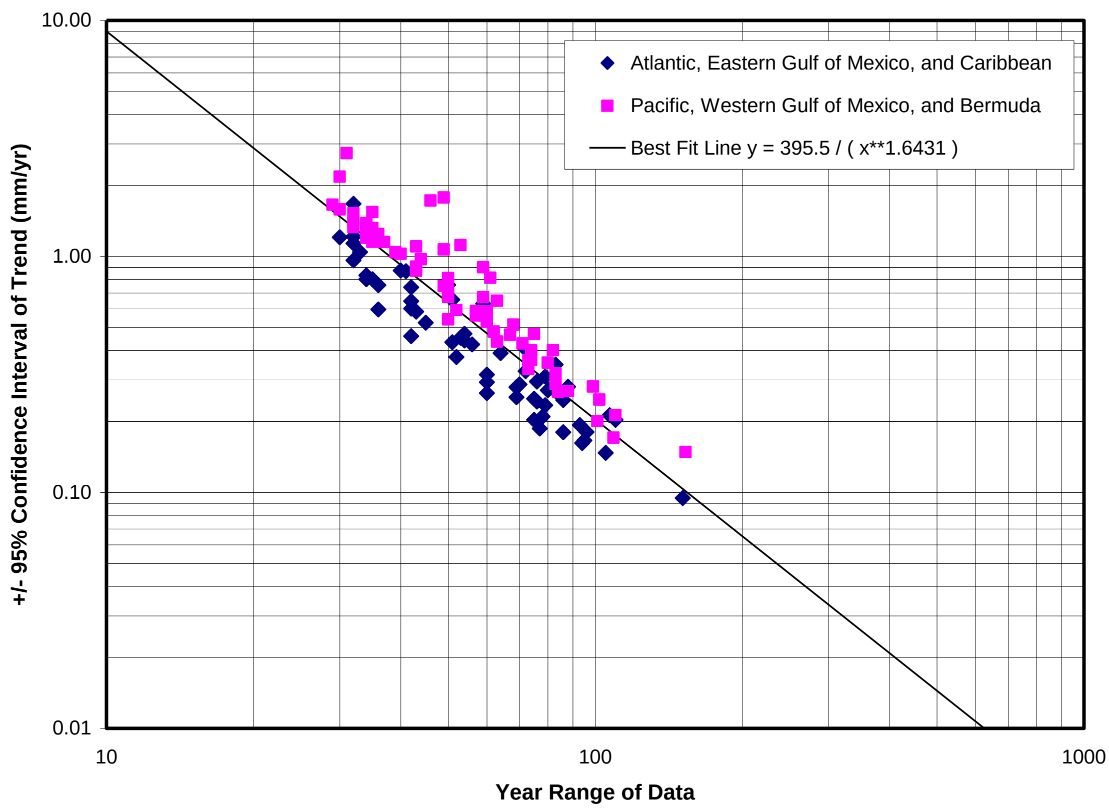


Figure 29. +/- 95% confidence interval of linear MSL trends (mm/yr) versus year range of data. The least squares fitted line is also shown.

It is also apparent from Figures 28 and 29 that for the same year range of data, the Pacific, western Gulf of Mexico, and Bermuda stations have wider error bars than stations in the Atlantic, eastern Gulf of Mexico, and the Caribbean. The Pacific stations have a greater interannual variability due to the influence of ENSO events on the U.S. west coast and Alaska. The western Gulf of Mexico stations appear to alternate between periods of higher and lower rates of sea level rise in contrast to the steadier rates seen in the eastern Gulf of Mexico.

The width of the 95% confidence intervals according to the derived relationship in equation 8 is plotted in Figure 30 as a function of the year range of available data. It can be seen that to get a linear trend with a confidence interval of 1 mm/yr requires about 50-60 years of data. In contrast, when using only 20 years of data, the confidence interval will have a width of nearly 6 mm/yr.

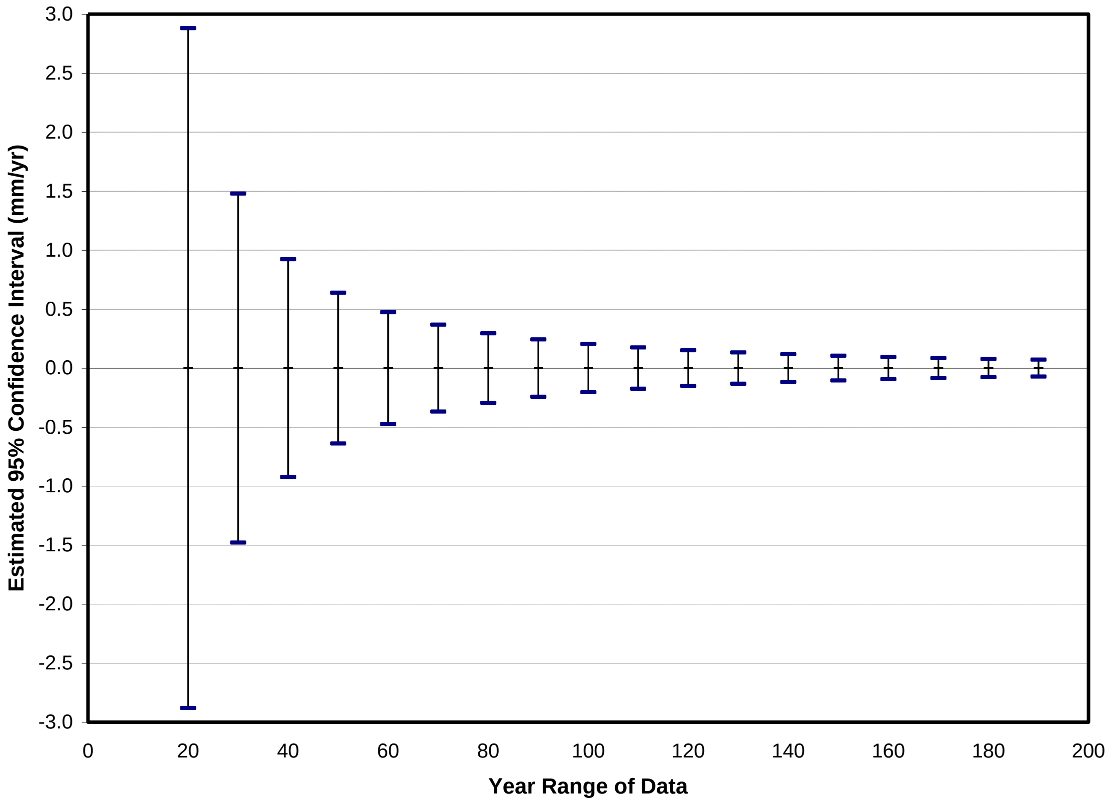


Figure 30. 95% confidence interval for linear MSL trend (mm/yr) versus year range of data based on equation 8.

Although MSL data sets that are unaffected by tectonic activity nearly always appear linear to first approximation, it is worth investigating whether there is any evidence of small changes in the trend over time. Often a time series is broken into subsets and a linear trend is calculated for each segment. Figure 30 indicates that if the subsets are too short, their trend uncertainties will be very large. In order to investigate small multidecadal variation in trends, the time series for 25 of the longest data sets (over 80 years of data) are divided into multiple 50-year segments each shifted by 5 years. The linear trends for every 50-year segment are listed in Table D in Appendix V. Plots of the multidecadal variation of the 50-year linear trends along with their 95% confidence intervals are also shown in Appendix V. A solid horizontal line on each plot shows the trend calculated from the entire time series for that station.

For most of the stations, the 95% confidence intervals of all the 50-year trends overlap, indicating no statistically significant variation in the long-term MSL rates. None of the long-term stations show a steady increase or a steady decrease in the 50-year trends. At some of the stations there is evidence of some statistically significant multidecadal variability. Stations on the U.S. east coast appear to have had higher MSL rates in the 1930s, 1940s, and 1950s and lower MSL rates in the 1960s and 1970s (Figure 31). There is only one long-term station where the trend for the last 50-year segment was statistically different than the overall trend; at Portland, the 1957-2006 trend is significantly lower than the overall trend. At Atlantic City and Sewells Point, the 1957-2006 trends (centered on 1982) are higher than any previous 50-year trend, but their 95% confidence intervals still include the overall trend.

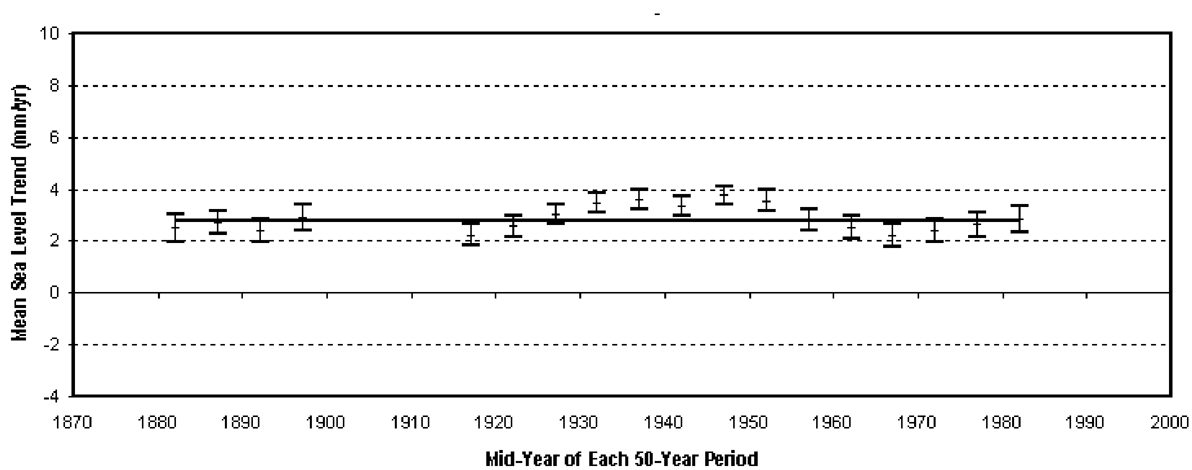
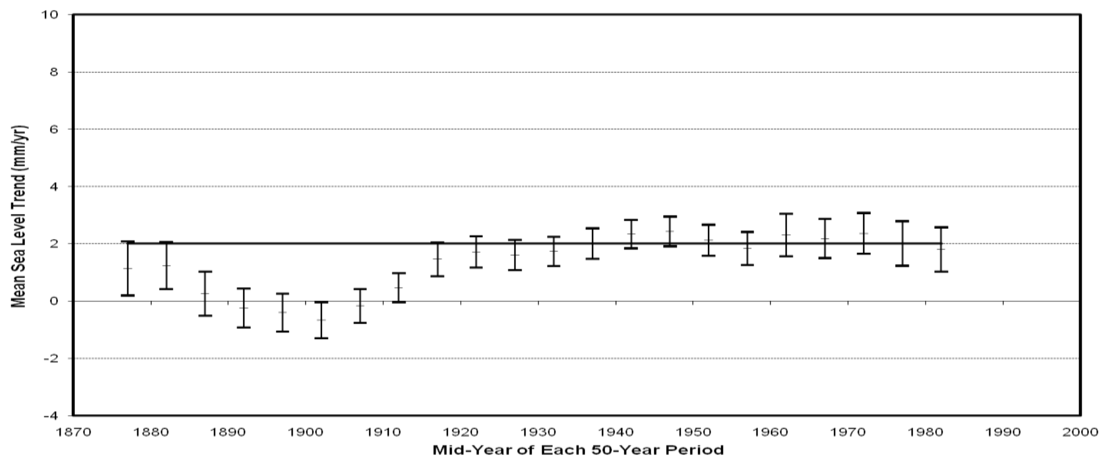


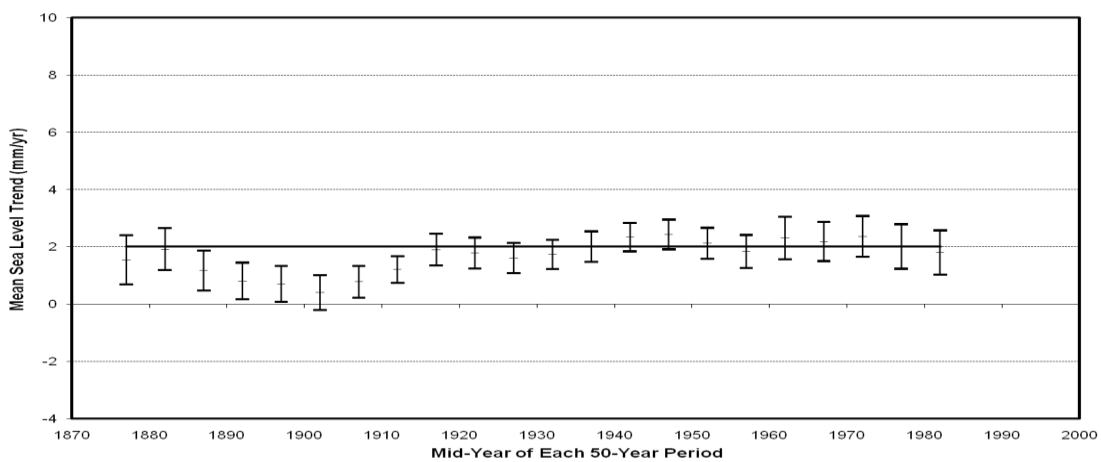
Figure 31. 50-year MSL trends with 95% confidence intervals at The Battery. Horizontal line is the MSL trend from all the data since 1856 (2.77 +/- 0.09 mm/yr).

At San Francisco, 50-year trends centered from 1885 to 1915 were significantly lower than the overall trend, with some periods actually having negative trends (Figure 32a). In Zervas (2001), it was hypothesized that this deviation from the long-term MSL trend was due to the tectonic effects of the 1906 earthquake. In this report, it is suggested that a small correction of 0.037 m be made to the time series in 1897, when the station was transferred from Sausalito to the Presidio. Using the adjusted series, the recalculated 50-year trends are displayed in Figure 32b. It can be seen that the lower trends around the year 1900 are still significantly less than the overall trend, but they are not negative. It is possible that there may still have been a small seismic offset in 1906 or the connection between the Sausalito and Presidio series in 1897 may still be incorrect.

CO-OPS has a policy of establishing a new NTDE every 20-25 years in order to derive new tidal datums to account for long-term relative sea level changes. The datums presently in effect are for the 1983-2001 NTDE. They went into effect in 2003 and replaced the datums for the previous 1960-1978 NTDE. The previous datums, which roughly represented the level of MSL in 1969 (the middle year of the NTDE), were still in effect up to 34 years after 1969, after a substantial amount of sea level change at some locations.



(a)



(b)

Figure 32. San Francisco 50-year MSL trends with 95% confidence intervals for the (a) original time series and (b) adjusted time series. Horizontal line is the MSL trend from all the data since 1897 (2.01 +/- 0.21 mm/yr).

By the 1990s, it had become apparent that in areas of rapid relative sea level change such as Louisiana, Texas, and Alaska, the tidal datums were becoming invalid for practical uses long before it was time for a nationwide update. Therefore for some stations, MSL datums derived for special 5-year MTDEs were introduced even while the 1960-1978 NTDE was still in effect. (For tidal datums other than MSL and MTL, such as MHW and MLW, the 19-year NTDEs are still used but the levels are re-adjusted to the elevation of the 5-year MTDE.) For Louisiana and Texas, a 1990-1994 MTDE was adopted; for Alaska, a 1994-1998 MTDE was adopted.

When the 1983-2001 NTDE was introduced, the regions with trends greater than 6 mm/yr were given MSL datums representing only the last 5 years of the new epoch (1997-2001). It was expected that these stations would require updates every 5 years because they would have changed by at least 0.030 m. When the 2002-2006 period was analyzed, due to the effects of interannual variability on the long-term trend, some of these stations had changed by less than 0.030 m while some other stations with smaller trends had changed by over 0.030 m.

Since CO-OPS will continue to use 5-year periods as an option to update datums in regions of rapid sea level change, a rule should be established for when to change to a new 5-year datum. It would be advantageous not to change the datums more often than necessary. It should also be kept in mind that if global sea level rise should accelerate in the future, more frequent updates would be required at many more stations.

For all the stations that have not been selected for a 5-year datum, Figure 33 shows the mean sea level for 2002-2006 relative to the 1983-2001 MSL datum still in effect. This 5-year period is centered on 2004 and represents roughly 12 years of MSL change since 1992. The values in Figure 33 are also affected by interannual variations and any small multidecadal changes in trend. Although some stations have changed little, many others have changed by more than 0.030 m. Therefore, not all currently accepted MSL datums reflect present-day MSL.

The next two 5-year datum periods will be 2007-2011 and 2012-2016, which will correspond to 17 years and 22 years after 1992, the center year of the current NTDE. CO-OPS will evaluate the changes in MSL and decide which stations will require a datum update in advance of the next nationwide update due sometime after 2020. Given current sea level trends, it is likely that most stations will be even further from the established NTDE datum than the values in Figure 33. If too many stations were to be switched to a 5-year datum to make them accurate to 0.030 m, the concept of a NTDE becomes obsolete. Therefore, the 0.030 m threshold may be too narrow of a tolerance in practice.

The absolute amounts of MSL change that can be expected 12 and 22 years after the center year of the NTDE, due solely to the relative MSL trends in Table 4, are plotted in Figure 34. If 0.l00 m were selected as the threshold for requiring a datum update, after 12 years (2002-2006) only the stations with trends above 8 mm/yr would likely require a new datum. After 22 years (2012-2016), only the stations with trends above 4.5 mm/yr would be likely to require a new datum when using a 0.100 m threshold.

All of the stations with trends above 6 mm/yr plus Freeport, Rockport, Anchorage, and Unalaska are already on a 5-year datum. Therefore, it is suggested that 0.100 m be adopted as a threshold for a 5-year datum update. When the MSL for a 5-year period is compared to the NTDE datum or to a previous 5-year MSL datum and the change is greater than 0.100 m, a new datum should be adopted. Because 19 out of 128 stations have trends above 4.5 mm/yr, only 15% of the long-term stations would have 5-year datums before a nationwide update is due. With a 0.100 m threshold for a datum update, only Skagway, the station with the greatest rate, will need to be updated every 5 years. The other stations with trends above 4.5 mm/yr will be able to remain on the same MSL datum for periods of 10 or even 15 years before requiring an update.

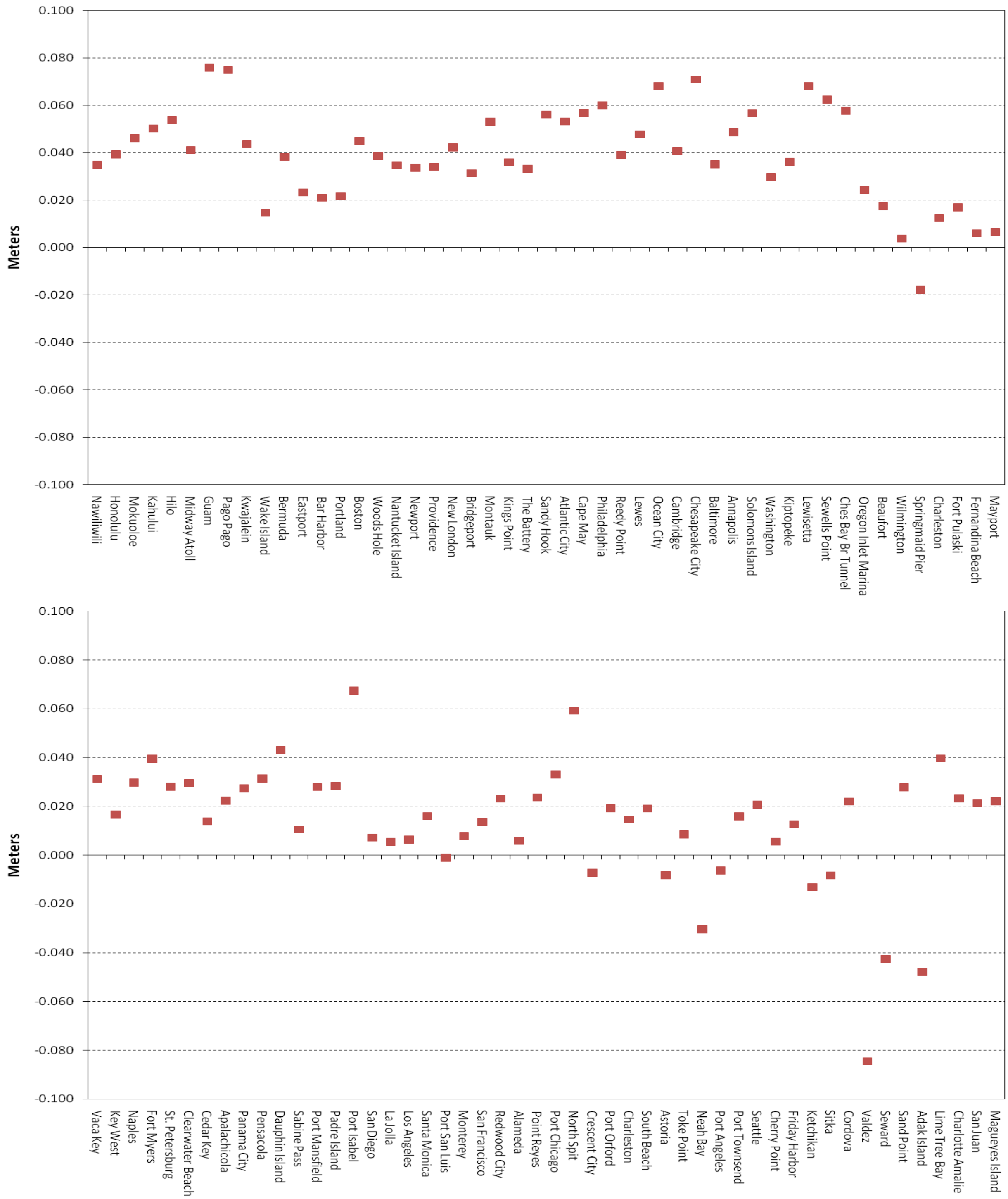


Figure 33. Mean sea level for 2002-2006 relative to the 1983-2001 MSL datum for stations that have not been updated to a 5-year MSL datum due to rapid relative sea level trends.

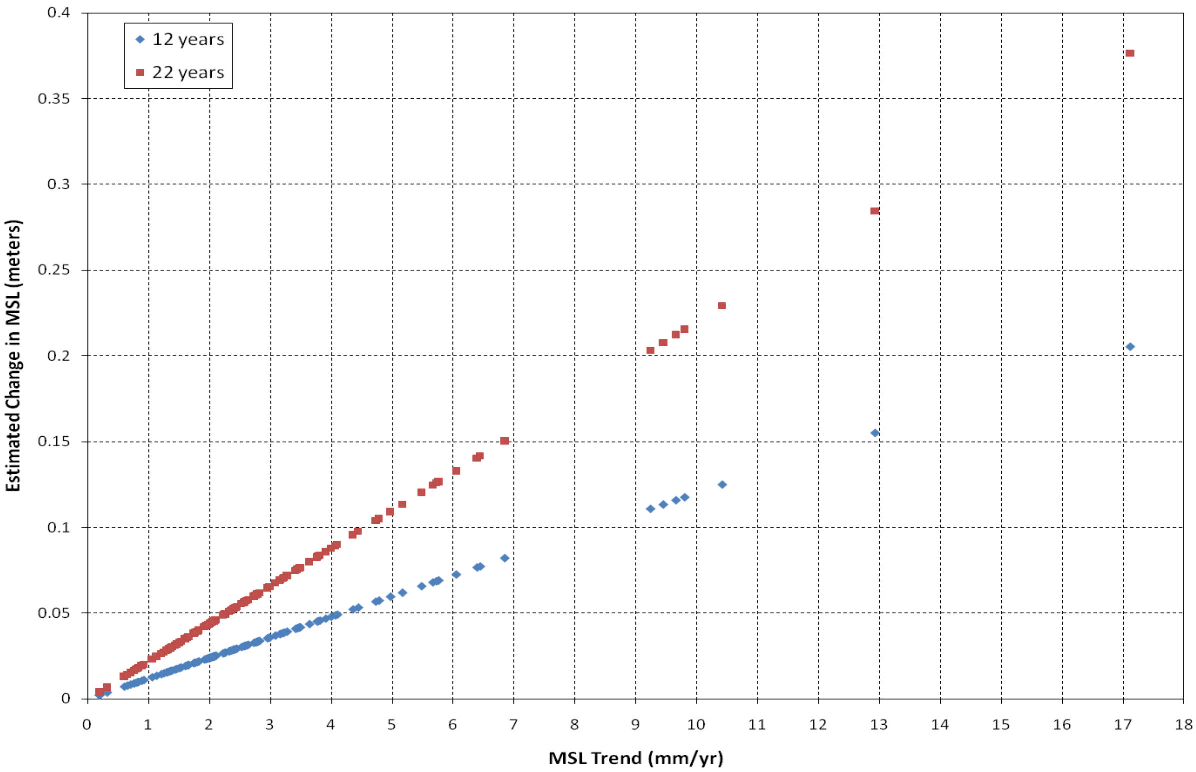


Figure 34. Estimated absolute MSL change for 12 and 22 years after the establishment of an NTDE as a function of the rate of sea level change.

CONCLUSION

This report is a re-analysis of mean sea level variations in the United States using monthly MSL data from long-term NWLON stations with a data range of at least 30 years. The report follows the format of Zervas (2001) with seven additional years of data and presents results for 12 additional stations. A total of 128 stations were analyzed for linear trends, autoregressive coefficients, average seasonal cycles, and interannual variability along with their 95% confidence intervals. The stations are located on the U.S. east and west coasts, the Gulf of Mexico, Alaska, Hawaii, Bermuda, the Caribbean, and on islands in the Pacific Ocean (Figures 1-7, Appendix I). The two oldest stations, The Battery and San Francisco, have records beginning in the 1850s. The maintenance of these long-term time series depends on the continued monitoring of tidal bench marks. The reference elevations of the station datums have been preserved despite the occasionally-required relocations of some of the stations.

Linear MSL trends were calculated using linear regression with an autoregressive coefficient of order 1 in order to obtain accurate error estimates. This method was used because of the serial correlation of the residual time series due to interannual variability caused by the effects of ENSO and other driving forces on coastal oceanic water temperatures, salinities, winds, air pressures, and currents. The linear trends range from 9.65 mm/yr at Eugene Island to -17.12 at Skagway (Table 4, Figures 9-11). The calculated trends are *relative* trends which are comprised of the absolute change in the level of the ocean and the vertical motion of the land. The global rate of sea level rise in the 20th century was 1.7 +/- 0.5 mm/yr (Solomon 2007). Although there were probably some smaller regional multidecadal variations in absolute sea level trends, most of the variation in relative sea level trends from station to station is due to local vertical land motions.

Time series plots for each station of the monthly MSL data with the average seasonal cycle removed are shown in Appendix II. The times of any major earthquakes in the vicinity are noted on the plots as a solid vertical line, because a seismic offset and/or a change in trend are possible. Separate pre-seismic and post-seismic trends were calculated at Guam, Yakutat, Cordova, Seward, Kodiak Island, Adak Island, and Unalaska due to observed seismic offsets in 1957, 1964, or 1993. Post-seismic trends usually indicate more rapid vertical land motion than pre-seismic trends.

The average seasonal cycles represented by twelve monthly values are plotted in Appendix III for each station, indicating the regular, repeatable variation in water levels over the course of a year. This variation is incorporated into the CO-OPS tidal predictions via two tidal constituents, Sa and Ssa. The twelve monthly values for each station's average seasonal cycle are used to derive values for Sa and Ssa which are listed in Appendix IV and compared to the accepted CO-OPS tidal constituents used for the official tide tables.

When the linear trend and the average seasonal cycle are removed from the monthly MSLs, the residual time series, representing regional oceanic interannual variability, are highly correlated from station to station. A 5-month running average of the residual time series is used to define times of unusually high or low water levels. When the 5-month running average is above 0.1 m or below -0.1 m, a positive or negative anomaly is defined. A table of the number of months with positive or negative anomalies each year (Tables 6 and 7), shows the timing and regional extent of anomalous water levels along a coastline. The major driver of anomalies on the U.S. west coast and in the western Pacific Ocean is ENSO variability. East coast and Gulf coast anomalies appear to be caused by multiple driving forces without any single dominant forcing.

Each derived linear trend has an associated uncertainty represented by error bars showing the 95% confidence interval. The 95% confidence intervals of the MSL trends can be related to the year range of data by an inverse power relationship. This empirically-derived relationship indicates how poorly-defined a linear trend derived from only 20 years of data can be. In contrast, a trend derived from 50-60 years of data is more precisely defined since it is much less affected by the interannual variability found in MSL time series. In general, for a given length of data, error bars are wider for Pacific Ocean and western Gulf of Mexico stations than for Atlantic Ocean and eastern Gulf of Mexico stations due to the different amplitudes of interannual variability.

Since trends derived from 50 years of MSL data have relatively small error bars, a long-term time series can be divided up into 50-year segments and an examination of their trends and associated confidence intervals can determine whether there is a statistically significant multidecadal variation in the time series. The 25 stations with the longest time series (over 80 years of data) have been divided into series of 50-year segments each offset by 5 years to determine how the MSL trends change over time. Most stations showed no long-term increase or decrease in the 50-year trends, but some Atlantic coast stations had statistically significant multidecadal variability with slightly higher trends in the 1930s, 1940s, and 1950s and slightly lower trends in the 1960s and 1970s. The greatest multidecadal variability was found in the longest NWLON series at San Francisco, where 50-year trends centered near the year 1900 were actually negative. A re-examination of the history of the San Francisco time series, which was put together with data from 3 separate locations, indicated the possibility of an error in the connection between the Sausalito and the Presidio series occurring in 1897. When the time series is adjusted and the 50-year trends are recalculated, the 50-year trends around 1900 are still significantly lower than the overall trend but they are not negative.

One of the consequences of changing sea levels is that most datums defined by CO-OPS become obsolete after several decades. The concept of a 19-year NTDE, introduced to define a MSL datum for a specific time period, requires a nationwide change to a new NTDE after 20-25 years when a sufficient amount of sea level change has taken place at most stations. In some regions, extremely rapid rates of relative sea level change required the introduction of special 5-year MSL datums. Some NWLON stations are currently on a 1997-2001 MTDE and some are on a 2002-2006 MTDE. Furthermore, some of the stations on the 1983-2001 NTDE are gradually drifting away from their established MSL datum. In this report, it is proposed that a new datum be introduced when MSL at a station, calculated over a 5-year period, has changed by over 0.100 m from its previously established datum. If this rule is adopted, only about 15% of the NWLON stations with the highest MSL trends would be on 5-year datums after 20-25 years, when a new NTDE can be established.

Eight NWLON stations now have data spanning periods of over 100 years. These stations are The Battery, Philadelphia, Baltimore, Fernandina Beach, San Diego, San Francisco, Seattle, and Honolulu. Figure 35 graphically summarizes these CO-OPS data sets and demonstrates the value of continuous, long-term sea level measurements. Together, these series represent the effect of globally-rising sea levels on most of the U.S. coastline. Although there is a small amount of subsidence at The Battery, Philadelphia, and Baltimore (about 1 mm/yr), the other five stations have negligible vertical land motion and therefore have been recording the absolute global 20th century sea level rise of 1.7 mm/yr (Douglas, 1991). As shown in Figure 35, the importance of the demonstrated global sea level rise derived from the long-term sea level observations is analogous to the importance of the atmospheric CO_2 observations to the global climate system.

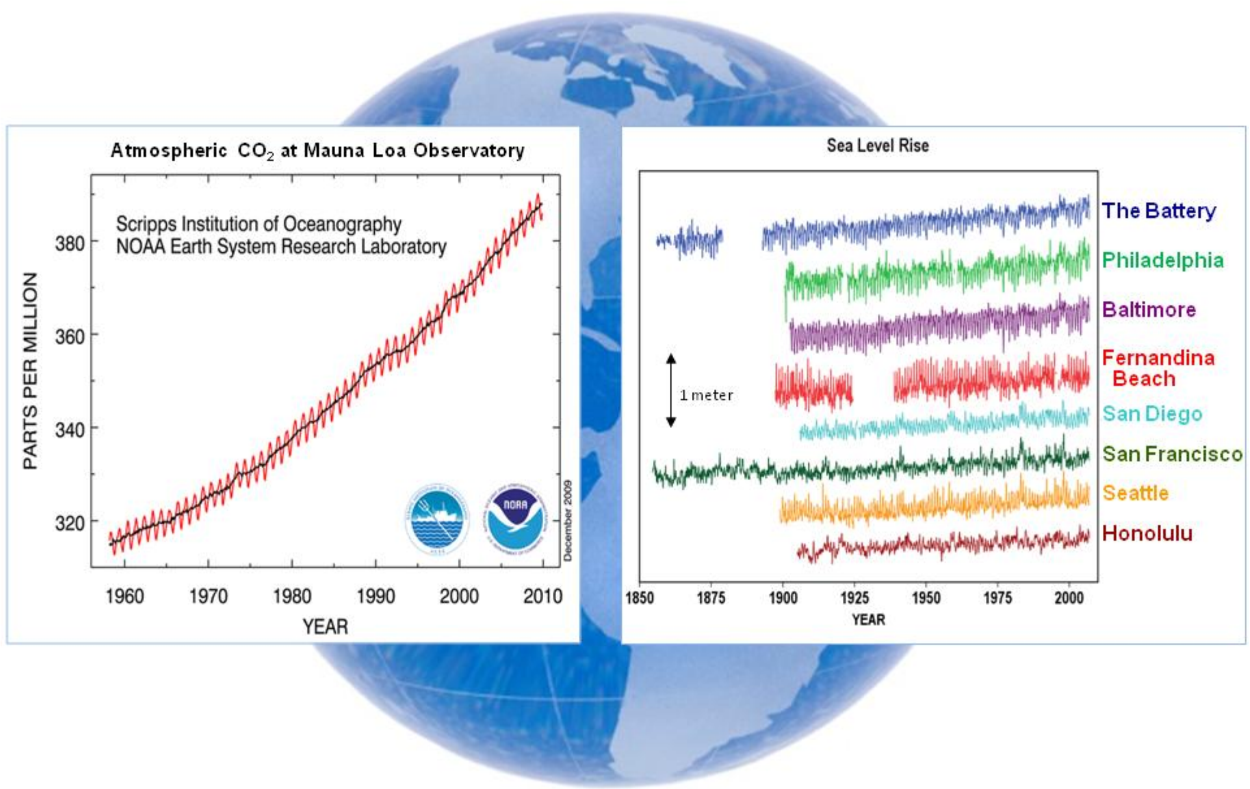


Figure 35. Comparison of the atmospheric carbon dioxide record at Mauna Loa, Hawaii since 1958 (from http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html) and monthly mean sea levels at eight NWLON stations with record lengths of over 100 years.

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APPENDICES

APPENDIX I

National Water Level Observation Network Stations

APPENDIX II

Time series of monthly mean sea level after removal of the average seasonal cycle showing the derived linear trend

APPENDIX III

Average seasonal cycle of monthly mean sea level with 95% confidence intervals

APPENDIX IV

Comparison of Sa and Ssa tidal constituents derived from average seasonal cycles with the accepted tidal constituents used for CO-OPS tide predictions

APPENDIX V

Linear trends for 50-year periods of mean sea level data

Appendix I.

National Water Level Observation Network Stations

Table A. NWLON Stations							
Station Number	**Latitude**	**Longitude**	**First Year**	**Last Year**	**Year Range**	**Station Name**	**State or Territory**
1611400	21.955	-159.357	1955	2006	52	Nawiliwili	Hawaii
1612340	21.307	-157.867	1905	2006	102	Honolulu	Hawaii
1612480	21.437	-157.793	1957	2006	50	Mokuoloe	Hawaii
1615680	20.898	-156.472	1947	2006	60	Kahului	Hawaii
1617760	19.73	-155.057	1927	2006	80	Hilo	Hawaii
1619000	16.738	-169.53	1947	2003	57	Johnston Atoll	
1619910	28.212	-177.36	1947	2006	60	Midway Atoll	
1630000	13.442	144.653	1948	1993	46	Guam	Marianas Is.
1770000	-14.28	-170.69	1948	2006	59	Pago Pago	American Samoa
1820000	8.737	167.738	1946	2006	61	Kwajalein	Marshall Is.
1840000	7.447	151.847	1947	1995	49	Chuuk	Caroline Is.
1890000	19.29	166.618	1950	2006	57	Wake Island	
2695535 2695540	32.373	-64.703	1932	2006	75	Bermuda	
8410140	44.903	-66.985	1929	2006	78	Eastport	Maine
8413320	44.392	-68.205	1947	2006	60	Bar Harbor	Maine
8418150	43.657	-70.247	1912	2006	95	Portland	Maine
8419870	43.08	-70.742	1926	2001	76	Seavey Island	Maine
8443970	42.355	-71.052	1921	2006	86	Boston	Massachusetts
8447930	41.523	-70.672	1932	2006	75	Woods Hole	Massachusetts
8449130	41.285	-70.097	1965	2006	42	Nantucket Island	Massachusetts
8452660	41.505	-71.327	1930	2006	77	Newport	Rhode Island
8454000	41.807	-71.402	1938	2006	69	Providence	Rhode Island
8461490	41.355	-72.087	1938	2006	69	New London	Connecticut
8467150	41.173	-73.182	1964	2006	43	Bridgeport	Connecticut
8510560	41.048	-71.96	1947	2006	60	Montauk	New York
8514560	40.95	-73.077	1957	1992	36	Port Jefferson	New York
8516990 8516945	40.81	-73.765	1931	2006	76	Willets Point / Kings Point	New York
8518750	40.7	-74.015	1856	2006	151	The Battery	New York
8531680	40.467	-74.01	1932	2006	75	Sandy Hook	New Jersey
8534720	39.355	-74.418	1911	2006	96	Atlantic City	New Jersey
8536110	38.968	-74.96	1965	2006	42	Cape May	New Jersey
8505530 8545240	39.933	-75.142	1900	2006	107	Philadelphia	Pennsylvania
8551910	39.558	-75.573	1956	2006	51	Reedy Point	Delaware
8557380	38.782	-75.12	1919	2006	88	Lewes	Delaware
8570280 8570283	38.328	-75.092	1975	2006	32	Ocean City	Maryland
8571890 8571892	38.573	-76.068	1943	2006	64	Cambridge	Maryland
8573927	39.527	-75.81	1972	2006	35	Chesapeake City	Maryland
8574680	39.267	-76.578	1902	2006	105	Baltimore	Maryland
8575512	38.983	-76.48	1928	2006	79	Annapolis	Maryland
8577330	38.317	-76.452	1937	2006	70	Solomons Island	Maryland
8594900	38.873	-77.022	1924	2006	83	Washington	D. C.

Table A. NWLON Stations							
Station Number	**Latitude**	**Longitude**	**First Year**	**Last Year**	**Year Range**	**Station Name**	**State or Territory**
8632200	37.167	-75.988	1951	2006	56	Kiptopeke	Virginia
8635150	38.252	-76.96	1972	2003	32	Colonial Beach	Virginia
8635750	37.995	-76.465	1974	2006	33	Lewisetta	Virginia
8637624	37.247	-76.5	1950	2003	54	Gloucester Point	Virginia
8638610	36.947	-76.33	1927	2006	80	Sewells Point	Virginia
8638660	36.822	-76.293	1935	1987	53	Portsmouth	Virginia
8638863	36.967	-76.113	1975	2006	32	Chesapeake Bay Bridge Tunnel	Virginia
8652587	35.795	-75.548	1977	2006	30	Oregon Inlet Marina	North Carolina
8656495 **8656483**	34.72	-76.67	1953	2006	54	Beaufort	North Carolina
8658120	34.227	-77.953	1935	2006	72	Wilmington	North Carolina
8659084	33.915	-78.018	1933	2006	74	Southport	North Carolina
8661000 **8661070**	33.655	-78.918	1957	2006	50	Springmaid Pier	South Carolina
8665530	32.782	-79.925	1921	2006	86	Charleston	South Carolina
8670870	32.033	-80.902	1935	2006	72	Fort Pulaski	Georgia
8720030	30.672	-81.465	1897	2006	110	Fernandina Beach	Florida
8720220 **8720218**	30.397	-81.43	1928	2006	79	Mayport	Florida
8721020 **8721120**	29.147	-80.963	1925	1983	59	Daytona Beach Shores	Florida
8723170	25.768	-80.132	1931	1981	51	Miami Beach	Florida
8723970	24.712	-81.105	1971	2006	36	Vaca Key	Florida
8724580	24.553	-81.808	1913	2006	94	Key West	Florida
8725110	26.13	-81.807	1965	2006	42	Naples	Florida
8725520	26.647	-81.872	1965	2006	42	Fort Myers	Florida
8726520	27.76	-82.627	1947	2006	60	St. Petersburg	Florida
8726724	27.978	-82.832	1973	2006	34	Clearwater Beach	Florida
8727520	29.135	-83.032	1914	2006	93	Cedar Key	Florida
8728690	29.727	-84.982	1967	2006	40	Apalachicola	Florida
8729108	30.152	-85.667	1973	2006	34	Panama City	Florida
8729840	30.403	-87.212	1923	2006	84	Pensacola	Florida
8735180	30.25	-88.075	1966	2006	41	Dauphin Island	Alabama
8761720 **8761724**	29.263	-89.957	1947	2006	60	Grand Isle	Louisiana
8764311	29.372	-91.385	1939	1974	36	Eugene Island	Louisiana
8770590 **8770570**	29.73	-93.87	1958	2006	49	Sabine Pass	Texas
8771450	29.31	-94.793	1908	2006	99	Galveston Pier 21	Texas
8771510	29.285	-94.788	1957	2006	50	Galveston Pleasure Pier	Texas
8772440	28.948	-95.308	1954	2006	53	Freeport	Texas
8774770	28.022	-97.047	1948	2006	59	Rockport	Texas
8778490	26.565	-97.43	1963	2006	44	Port Mansfield	Texas
8779750	26.068	-97.152	1958	2006	49	Padre Island	Texas
8779770	26.06	-97.215	1944	2006	63	Port Isabel	Texas
9410170	32.713	-117.173	1906	2006	101	San Diego	California
9410230	32.867	-117.258	1924	2006	83	La Jolla	California

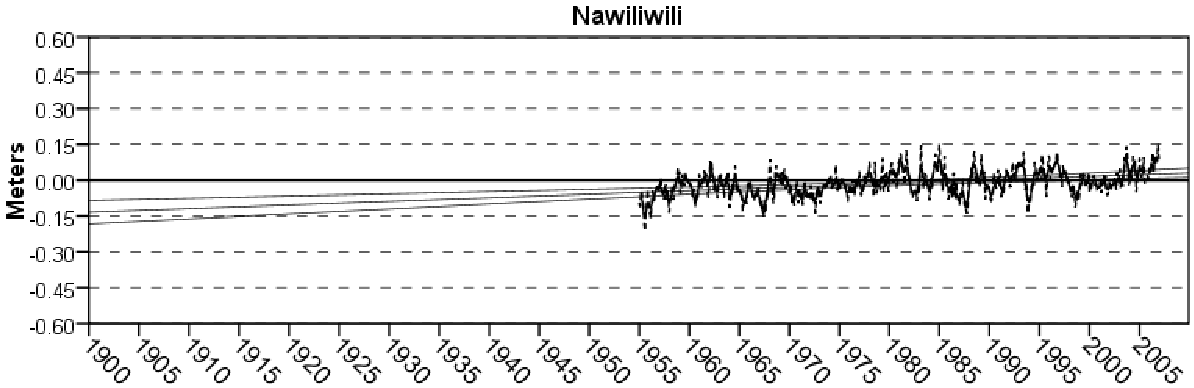
Table A. NWLON Stations							
Station Number	**Latitude**	**Longitude**	**First Year**	**Last Year**	**Year Range**	**Station Name**	**State or Territory**
9410580	33.603	-117.883	1955	1993	39	Newport Beach	California
9410660	33.72	-118.272	1923	2006	84	Los Angeles	California
9410840	34.008	-118.5	1933	2006	74	Santa Monica	California
9411270	34.348	-119.443	1962	1990	29	Rincon Island	California
9411340	34.408	-119.685	1973	2006	34	Santa Barbara	California
9412110	35.177	-120.76	1945	2006	62	Port San Luis	California
9413450	36.605	-121.888	1973	2006	34	Monterey	California
9414290	37.807	-122.465	1897	2006	110	San Francisco	California
9414523	37.507	-122.21	1974	2006	33	Redwood City	California
9414750	37.772	-122.298	1939	2006	68	Alameda	California
9415020	37.997	-122.975	1975	2006	32	Point Reyes	California
9415144	38.057	-122.038	1976	2006	31	Port Chicago	California
9418767	40.767	-124.217	1977	2006	30	North Spit	California
9419750	41.745	-124.183	1933	2006	74	Crescent City	California
9431647	42.74	-124.497	1977	2006	30	Port Orford	Oregon
9432780	43.345	-124.322	1970	2006	37	Charleston	Oregon
9435380	44.625	-124.043	1967	2006	40	South Beach	Oregon
9437540	45.555	-123.912	1970	2006	37	Garibaldi	Oregon
9439040	46.208	-123.767	1925	2006	82	Astoria	Oregon
9440910	46.708	-123.965	1973	2006	34	Toke Point	Washington
9443090	48.368	-124.617	1934	2006	73	Neah Bay	Washington
9444090	48.125	-123.44	1975	2006	32	Port Angeles	Washington
9444900	48.112	-122.758	1972	2006	35	Port Townsend	Washington
9447130	47.605	-122.338	1898	2006	109	Seattle	Washington
9449424	48.863	-122.758	1973	2006	34	Cherry Point	Washington
9449880	48.547	-123.01	1934	2006	73	Friday Harbor	Washington
9450460	55.333	-131.625	1919	2006	88	Ketchikan	Alaska
9451600	57.052	-135.342	1924	2006	83	Sitka	Alaska
9452210	58.298	-134.412	1936	2006	71	Juneau	Alaska
9452400	59.45	-135.327	1944	2006	63	Skagway	Alaska
9453220	59.548	-139.735	1940	2006	67	Yakutat	Alaska
9454050	60.558	-145.753	1964	2006	43	Cordova	Alaska
9454240	61.125	-146.362	1973	2006	34	Valdez	Alaska
9455090	60.12	-149.427	1964	2006	43	Seward	Alaska
9455500	59.44	-151.72	1964	2006	43	Seldovia	Alaska
9455760	60.683	-151.398	1973	2006	34	Nikiski	Alaska
9455920	61.238	-149.89	1972	2006	35	Anchorage	Alaska
9457292 **9457283**	57.732	-152.512	1975	2006	32	Kodiak Island	Alaska
9459450	55.337	-160.502	1972	2006	35	Sand Point	Alaska
9461380	51.863	-176.632	1957	2006	50	Adak Island	Alaska
9462611 **9462620**	53.88	-166.537	1957	2006	50	Unalaska	Alaska
9731158	19.907	-75.147	1937	1971	35	Guantanamo Bay	Cuba

Table A. NWLON Stations							
Station Number	**Latitude**	**Longitude**	**First Year**	**Last Year**	**Year Range**	**Station Name**	**State or Territory**
9751401	17.697	-64.753	1977	2006	30	Lime Tree Bay	Virgin Islands
9751639	18.335	-64.92	1975	2006	32	Charlotte Amalie	Virgin Islands
9755371	18.458	-66.117	1962	2006	45	San Juan	Puerto Rico
9759110	17.972	-67.047	1955	2006	52	Magueyes Island	Puerto Rico

APPENDIX II

Time series of monthly mean sea level after removal of the average seasonal cycle showing the derived linear trend

Note: Dashed line indicates the monthly MSL and solid line indicates the 5-month average. Derived linear trends and 95% confidence intervals for the trends are also shown. Vertical solid lines indicate times of major earthquakes. Dashed vertical lines indicate beginning and end of periods of suspect data. The zero value on the vertical axis represents the elevation of the MSL datum for the National Tidal Datum Epoch (1983-2001) or the special 5-year Modified Tidal Datum Epoch, as appropriate.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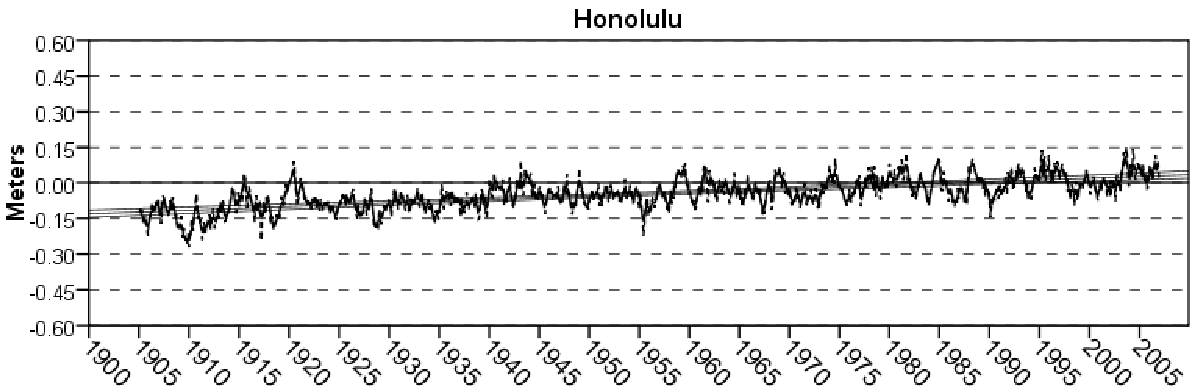
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0.15
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-0.30
-0.45
-0.60
Meters
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1905
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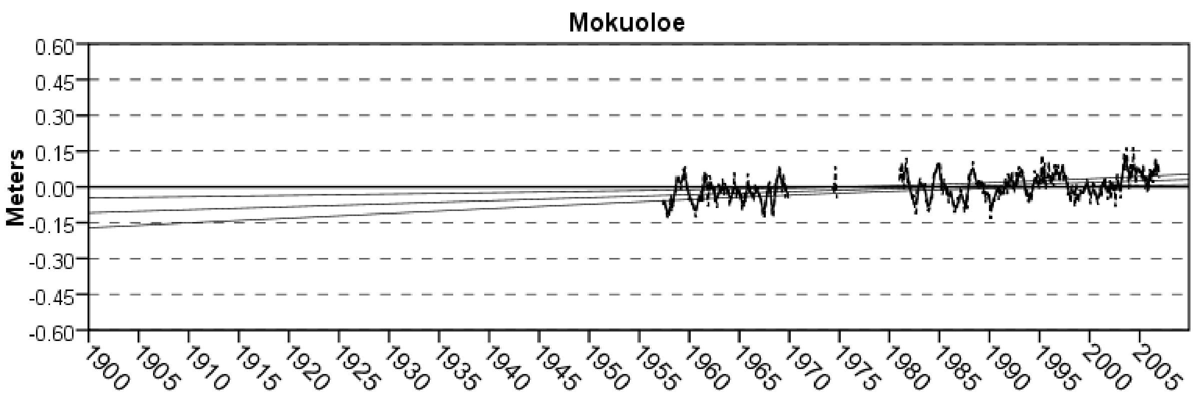
Mokuoloe
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-0.60
Meters
1900
1905
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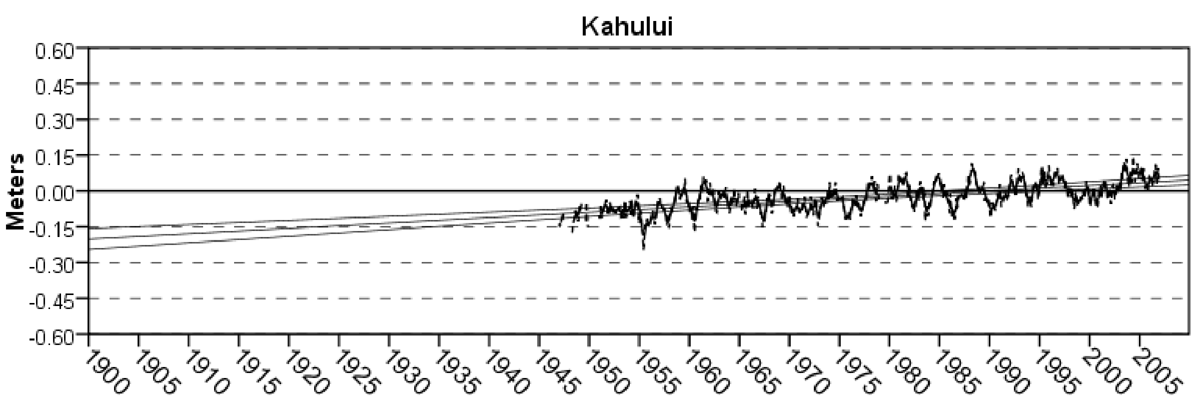
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Meters
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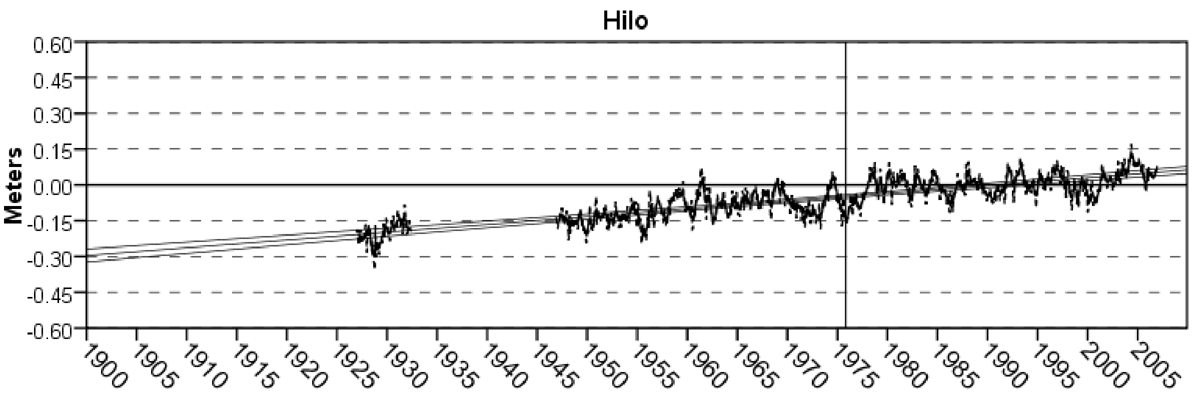
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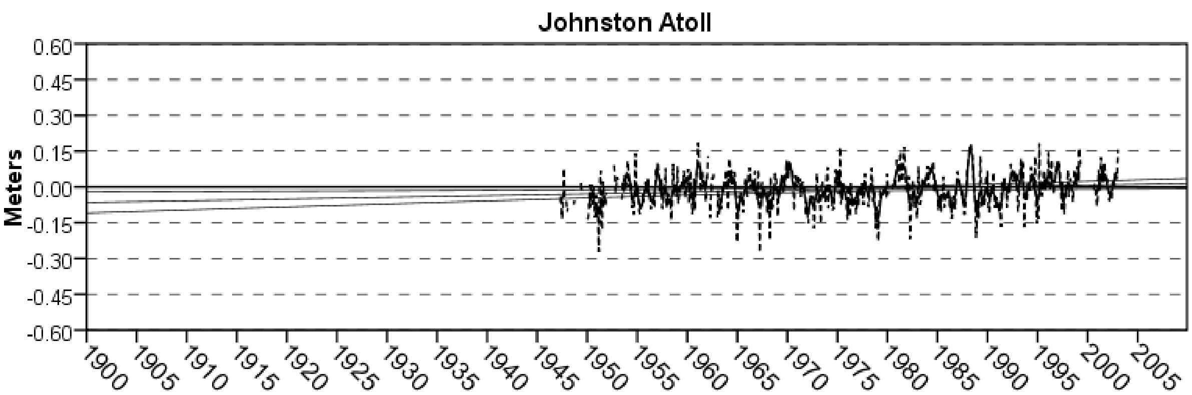
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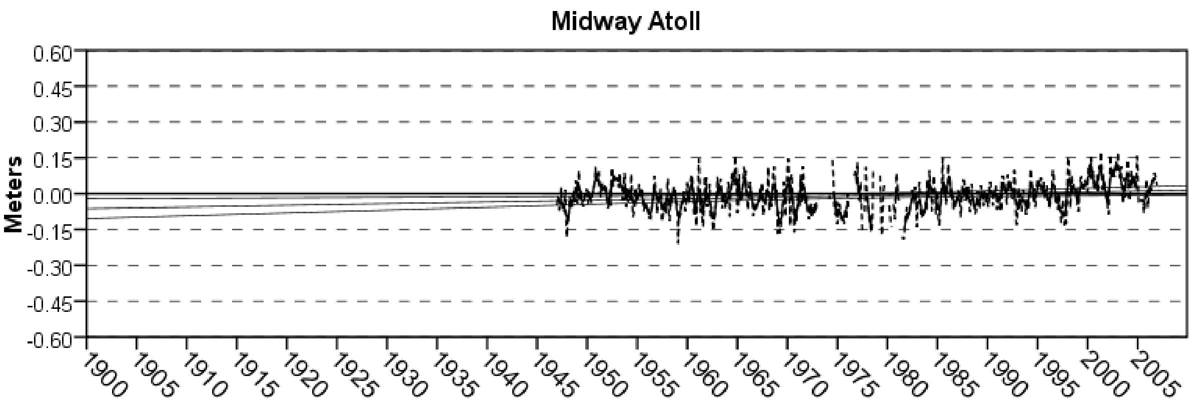
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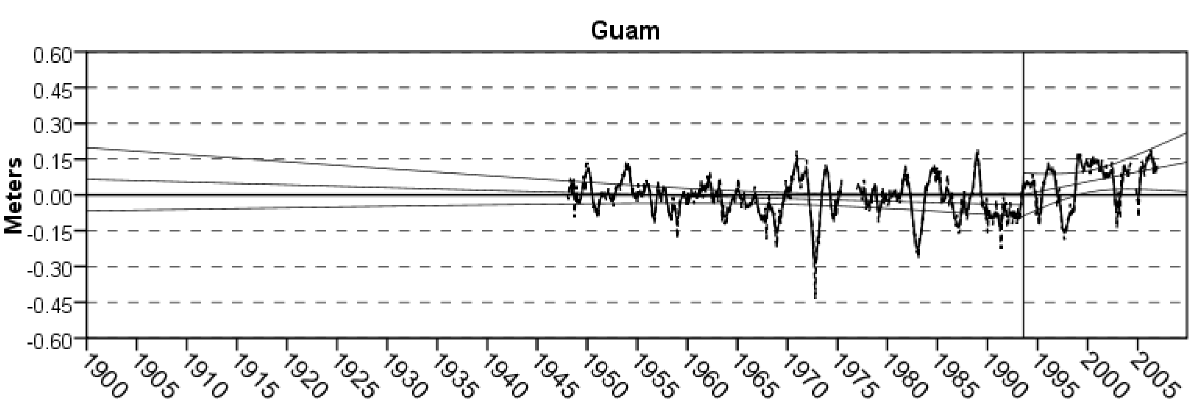
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005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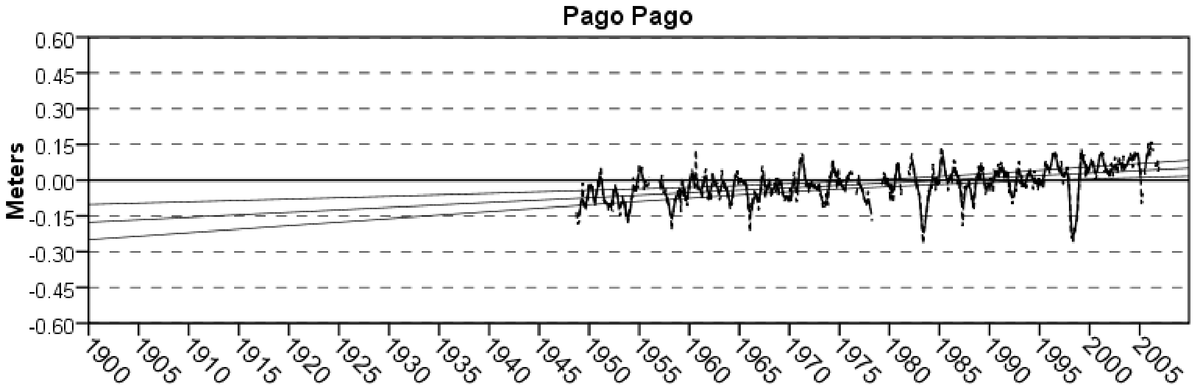
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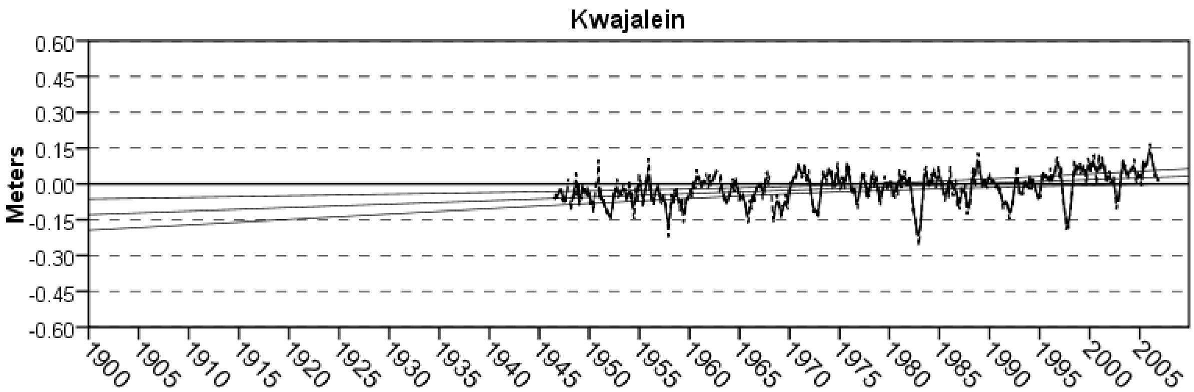
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005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Meters
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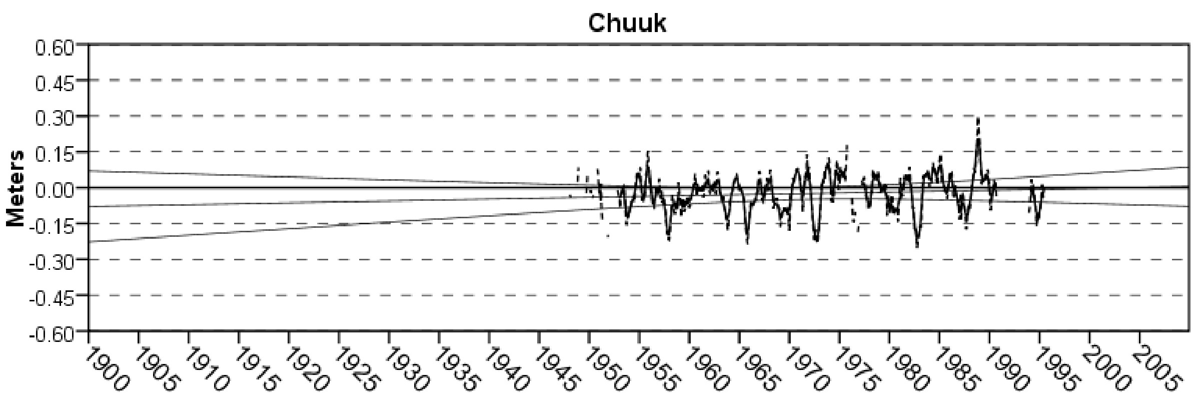
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005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Meters
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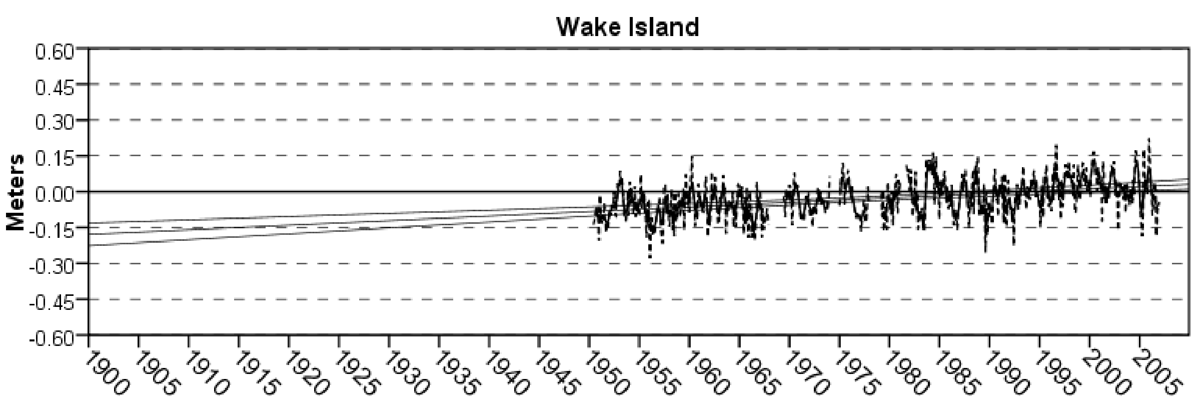
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005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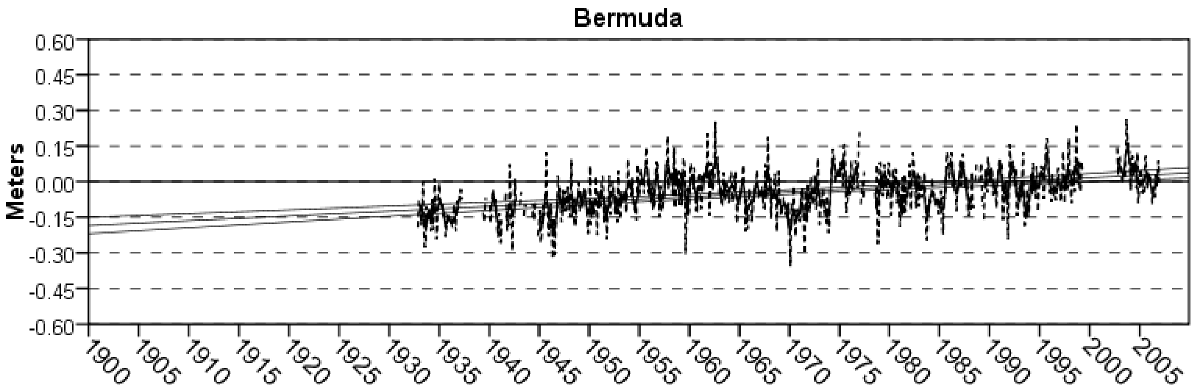
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005



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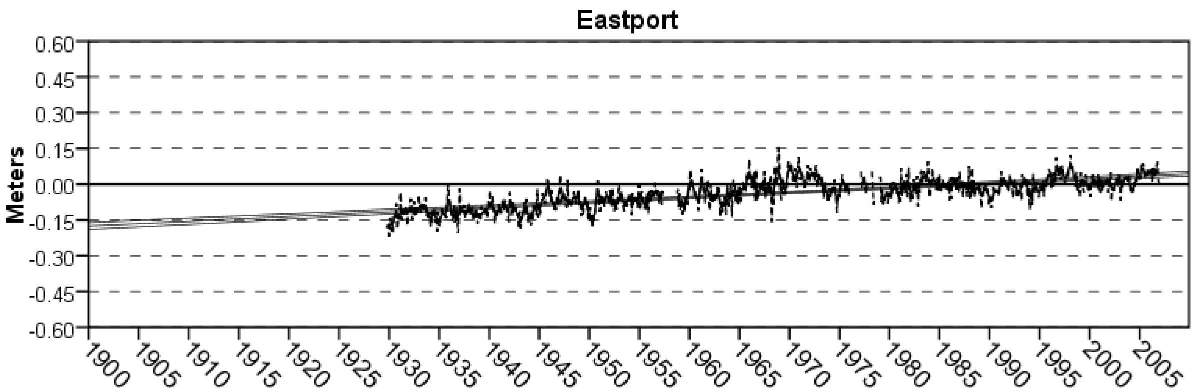
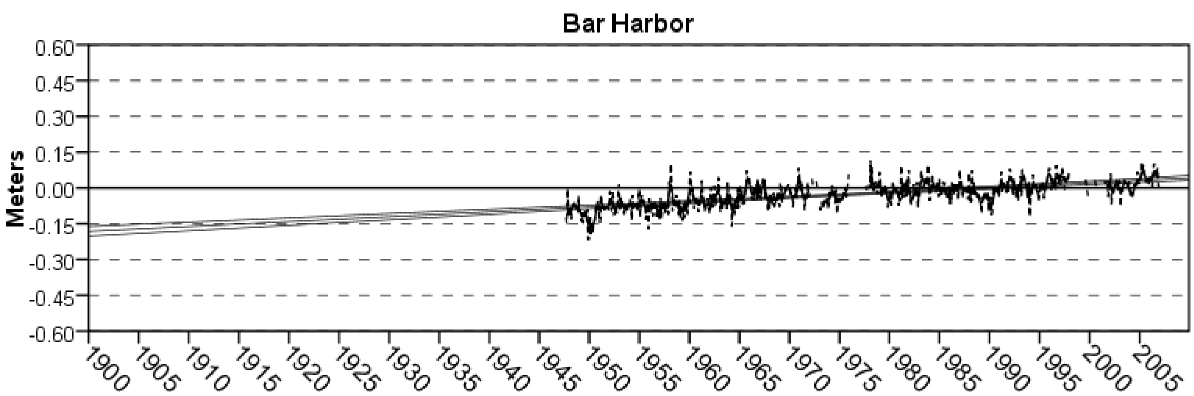
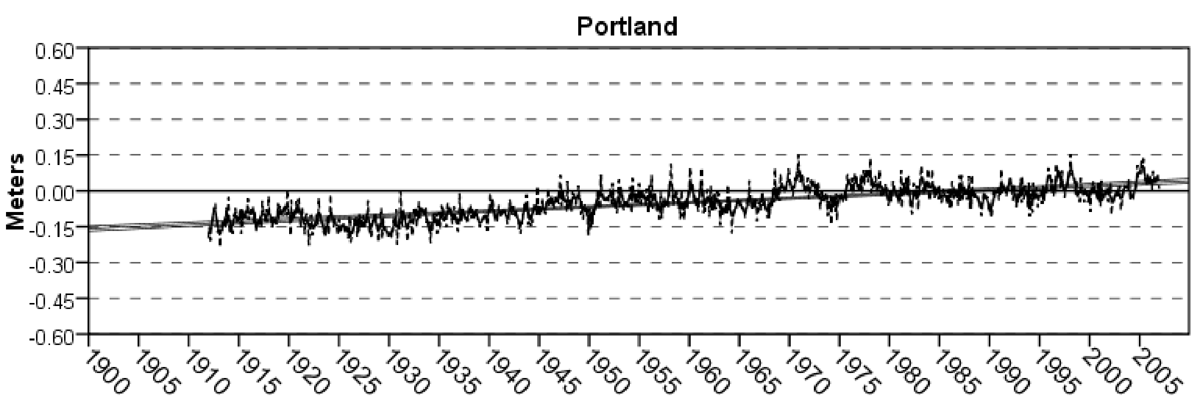
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005



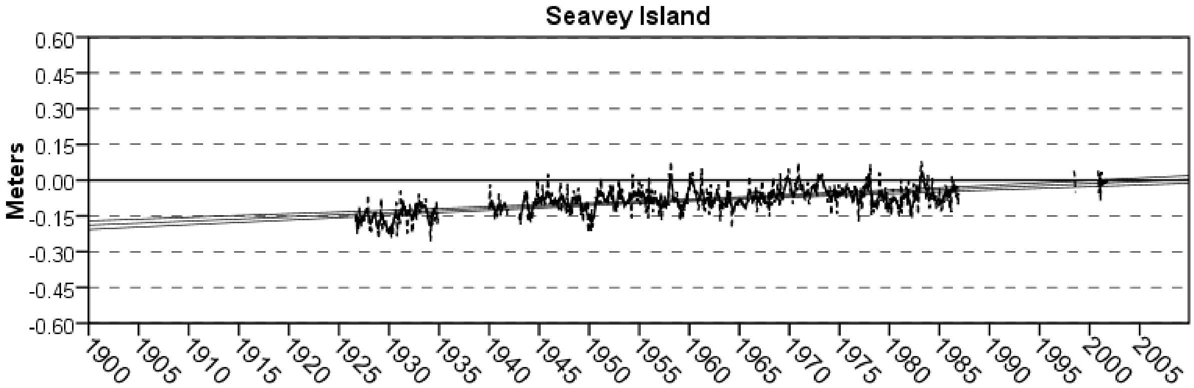
Eastport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

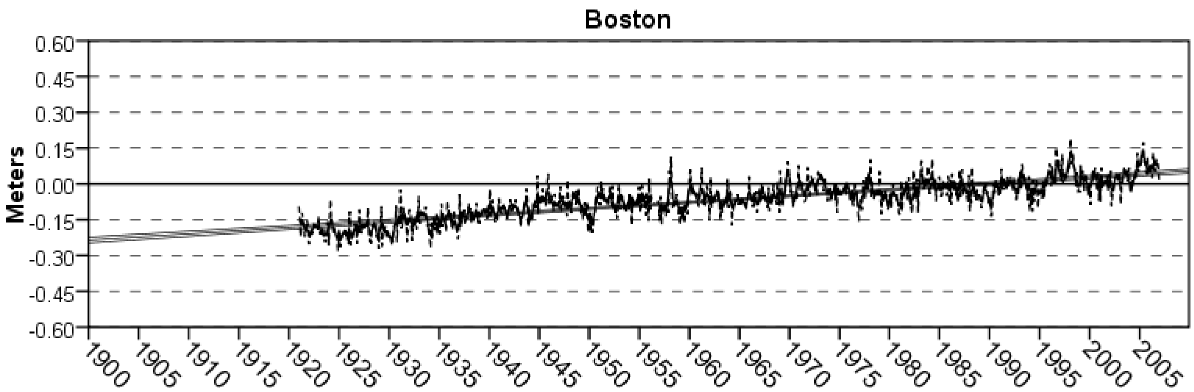


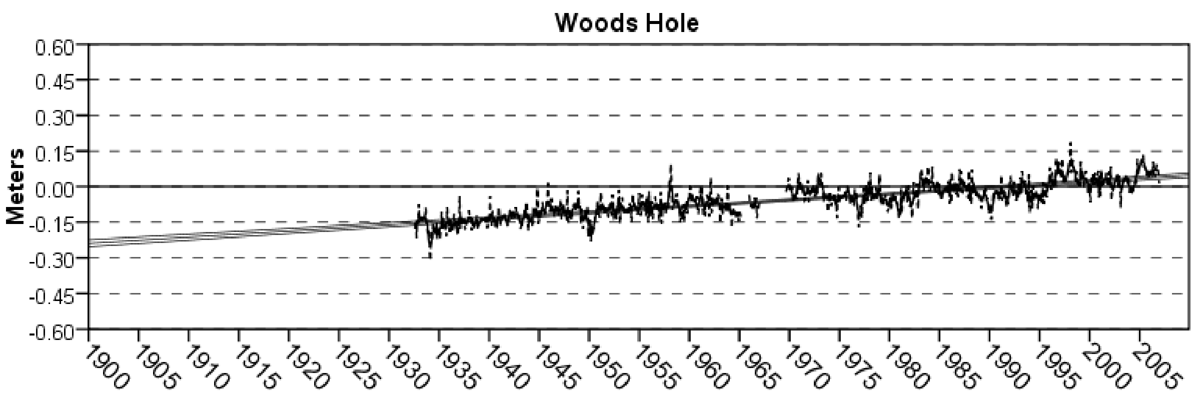
Bar Harbor
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

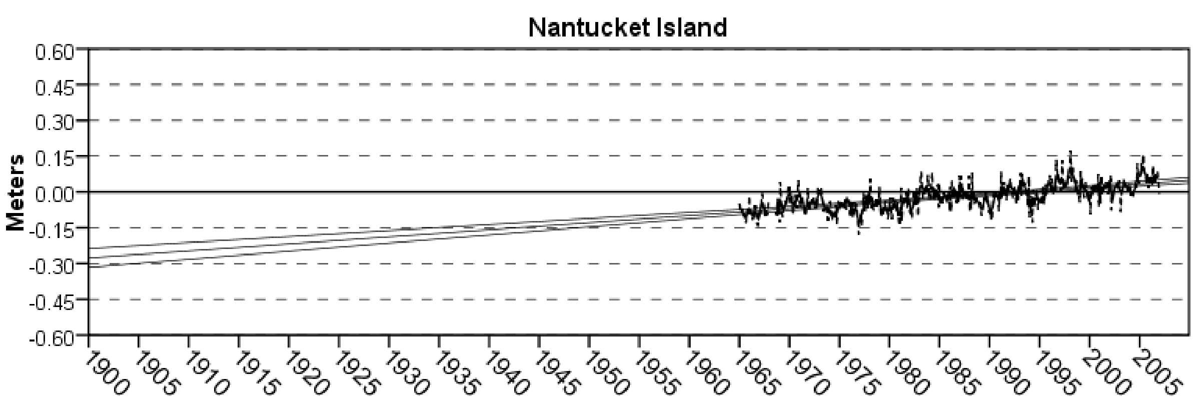


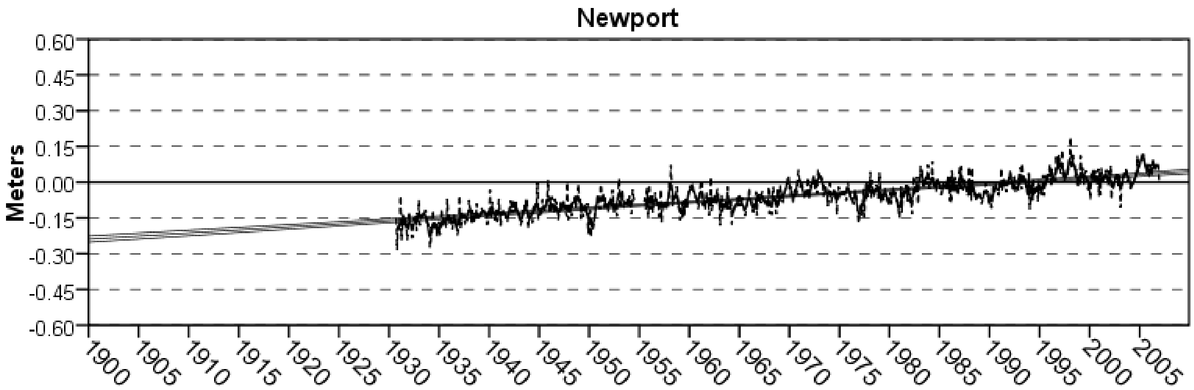
Portland
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

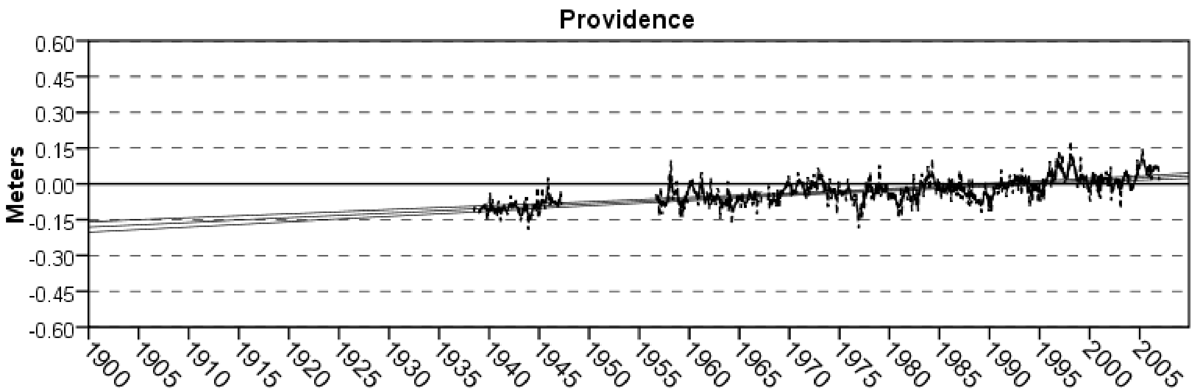

Seavey Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

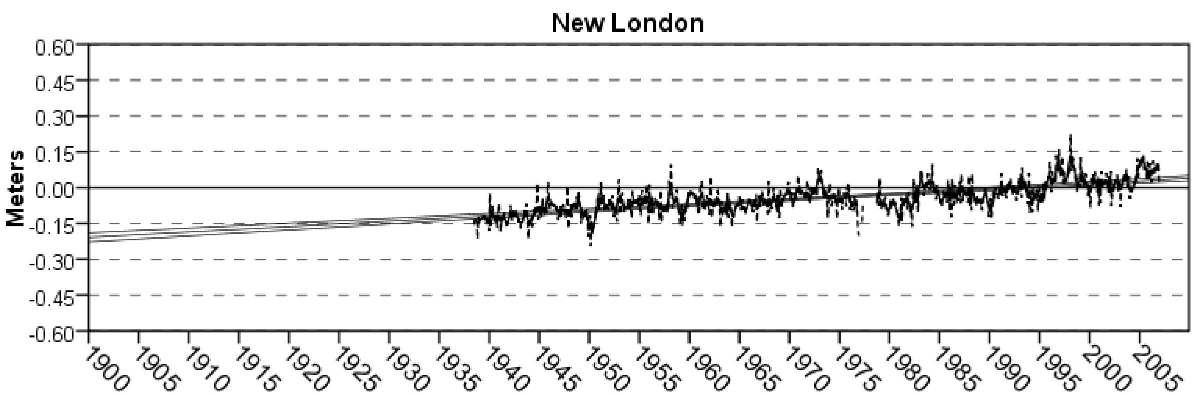

Boston
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Woods Hole
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Nantucket Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Newport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Providence
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


New London
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
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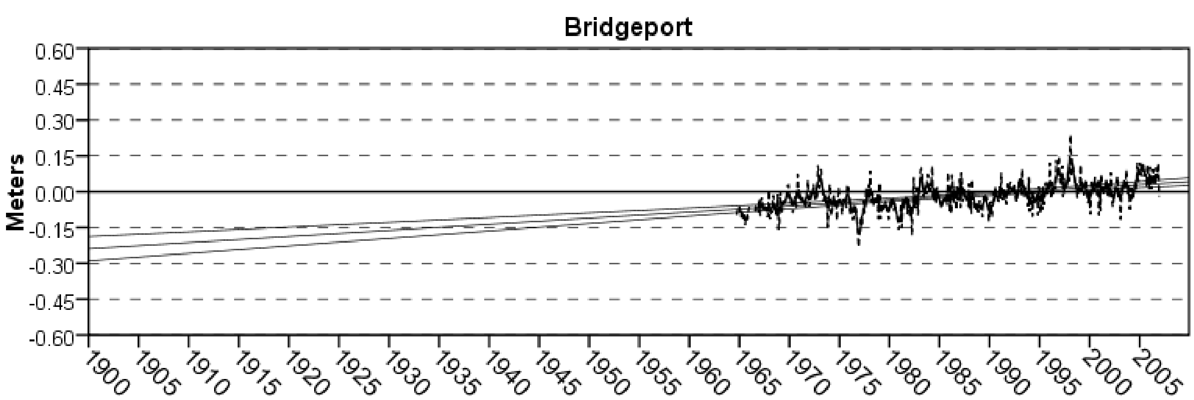
1980
1985
1990
1995
2000
2005


Bridgeport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
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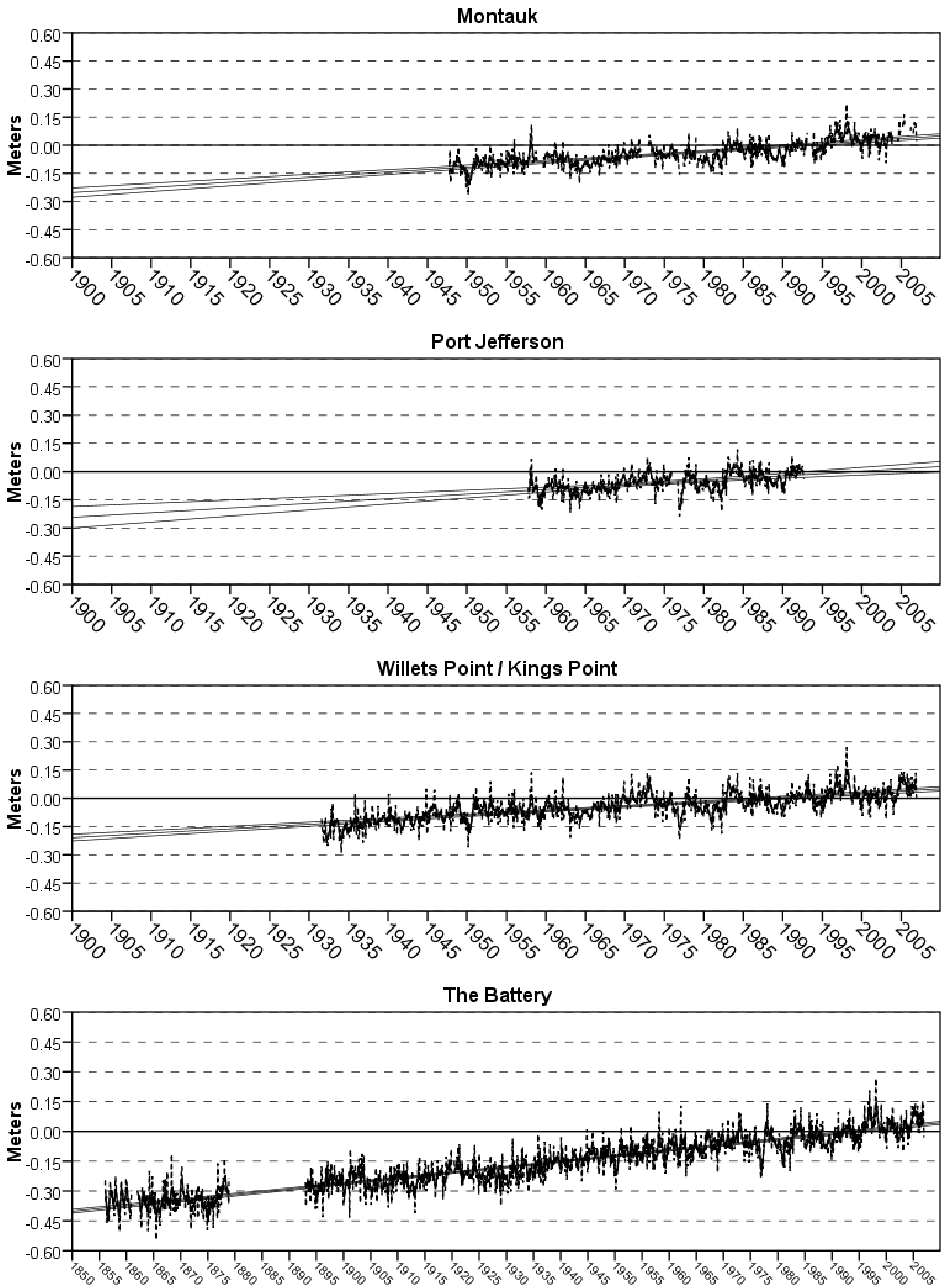
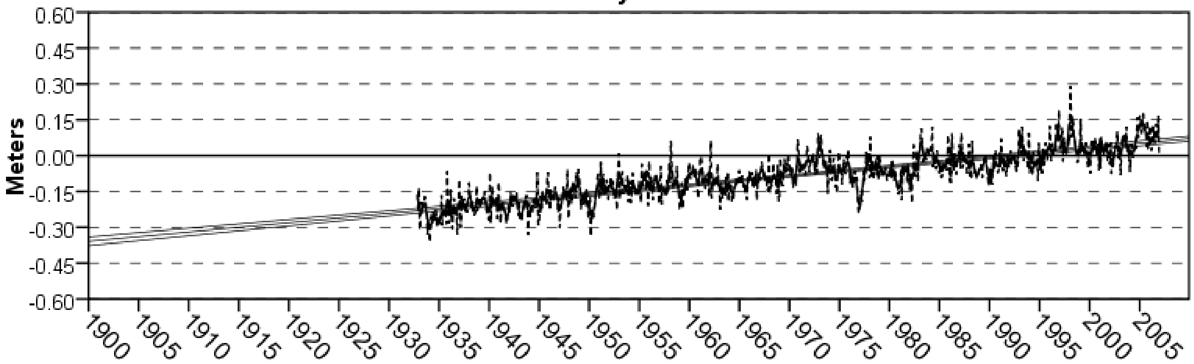
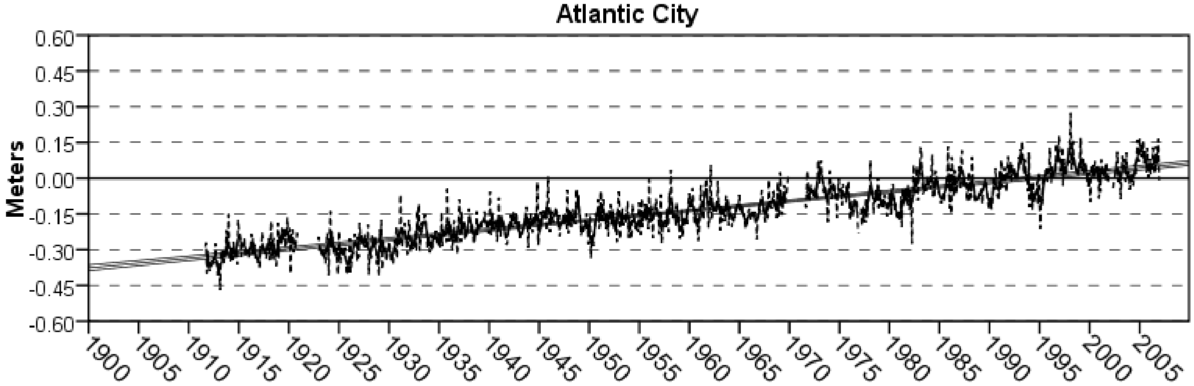
1985
1990
1995
2000
2005


Montauk
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
Port Jefferson
Willets Point / Kings Point
The Battery
1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

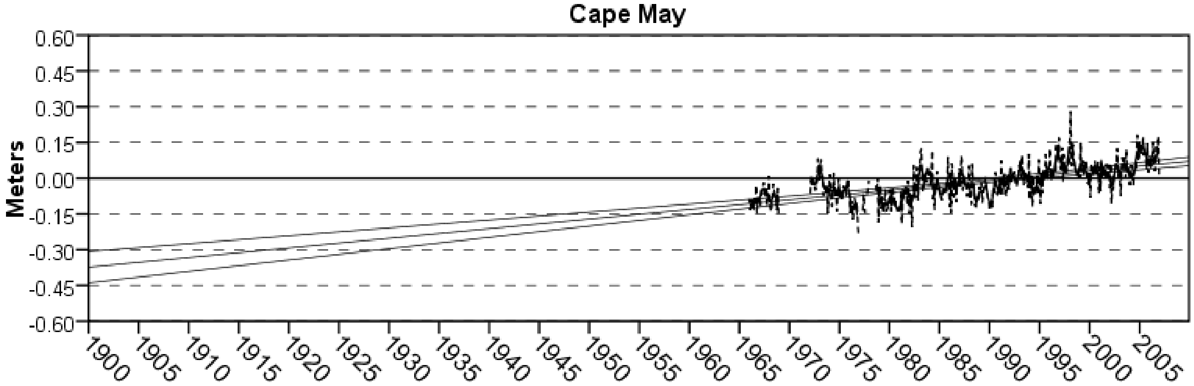
Sandy Hook



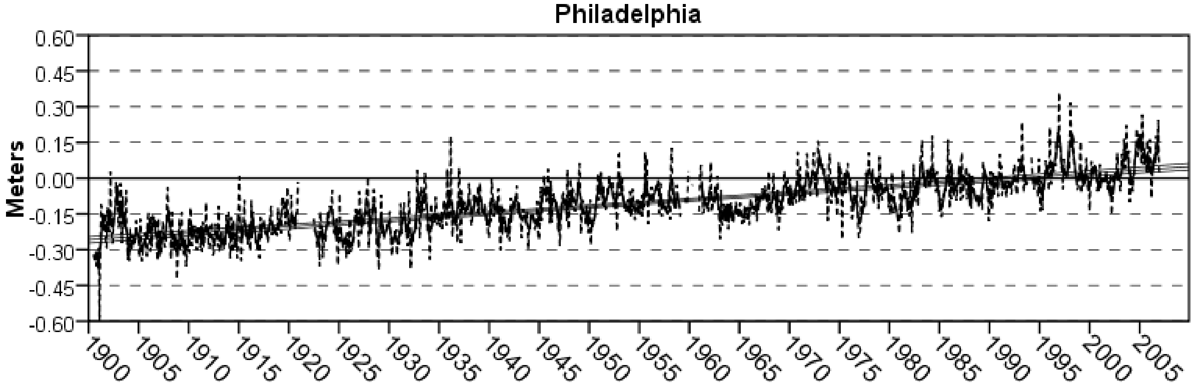
Atlantic City

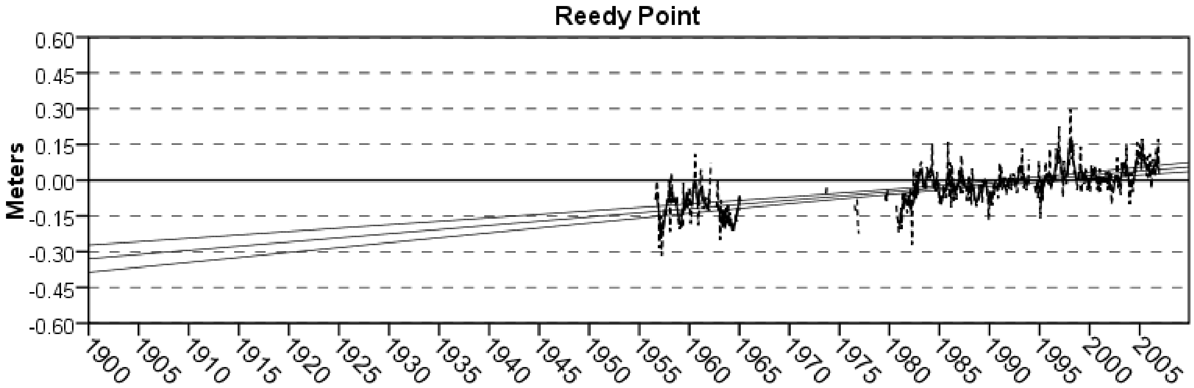


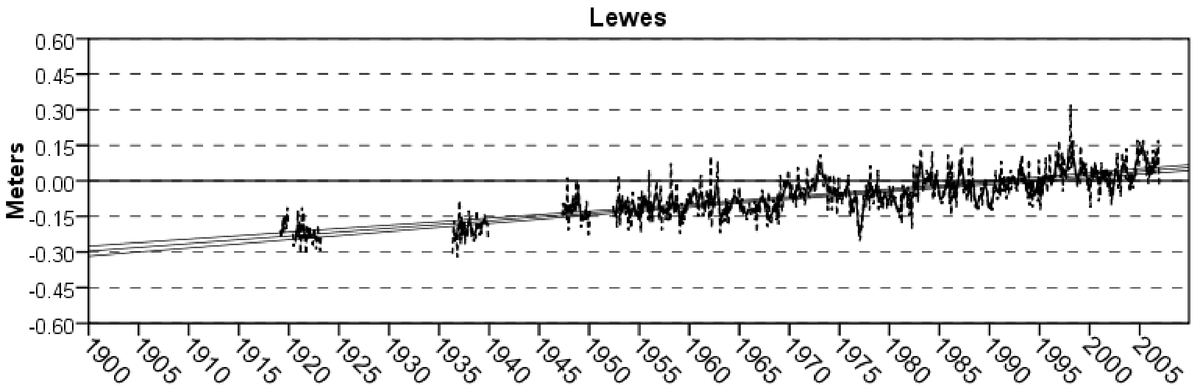
Cape May

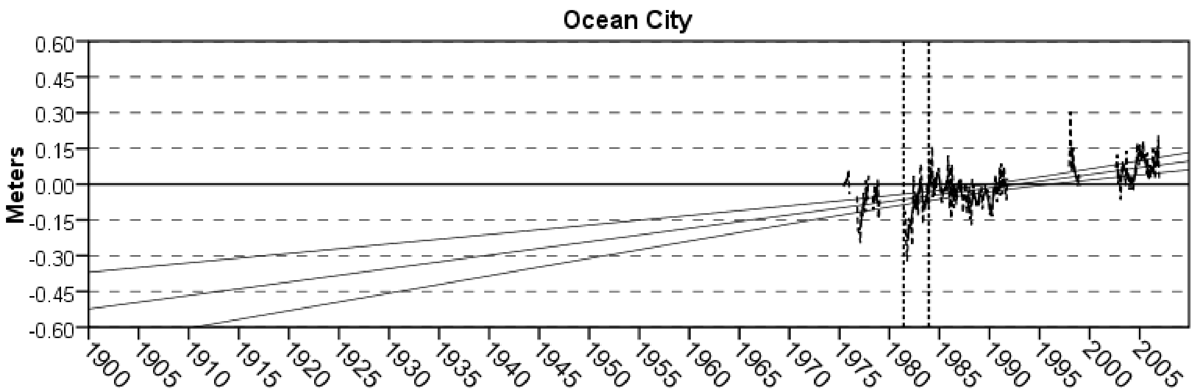


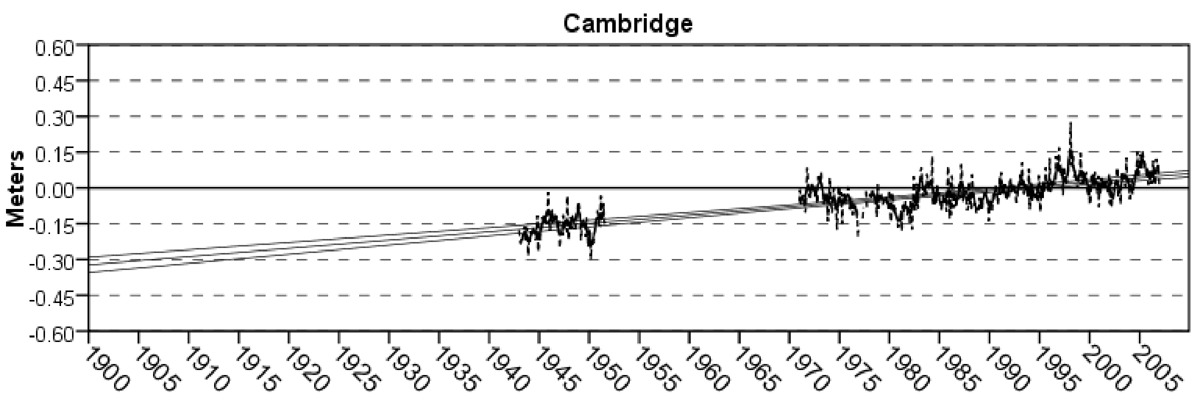
Philadelphia

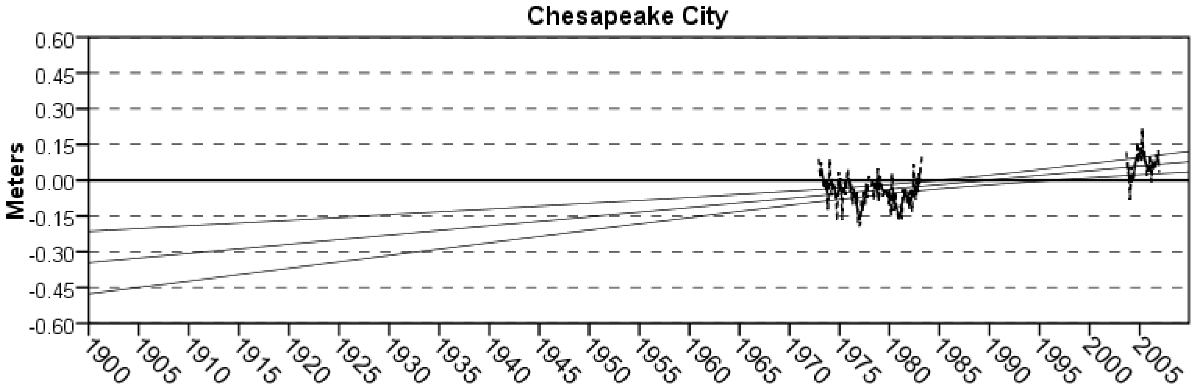


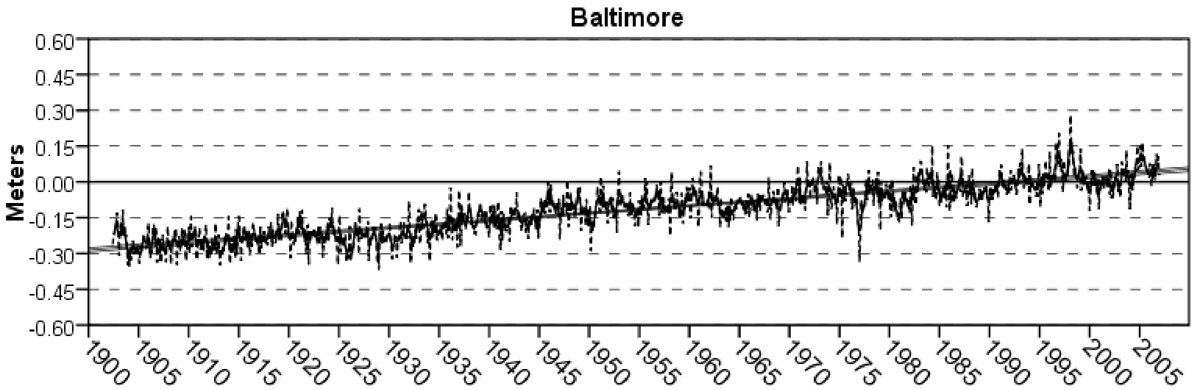

Reedy Point
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

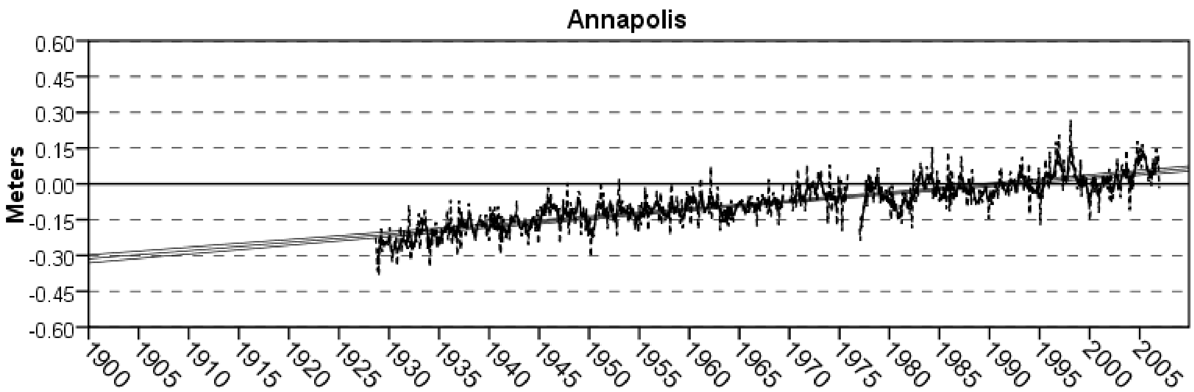

Lewes
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

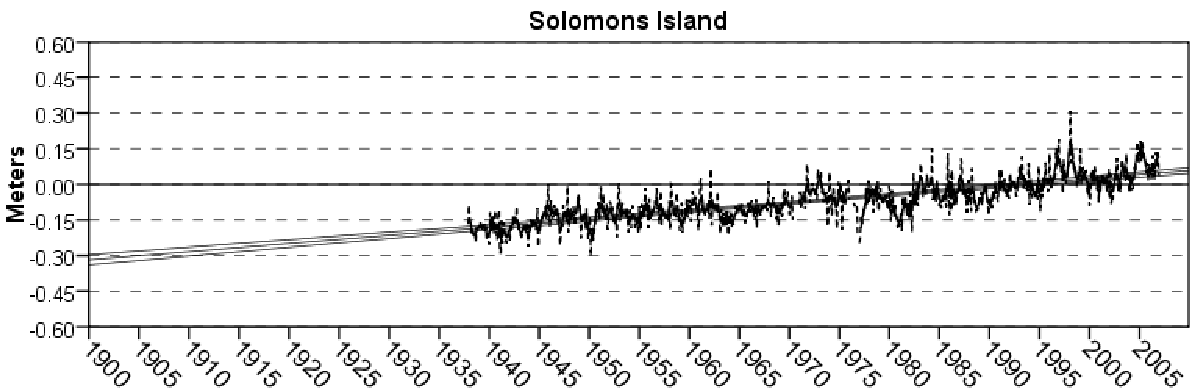

Ocean City
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

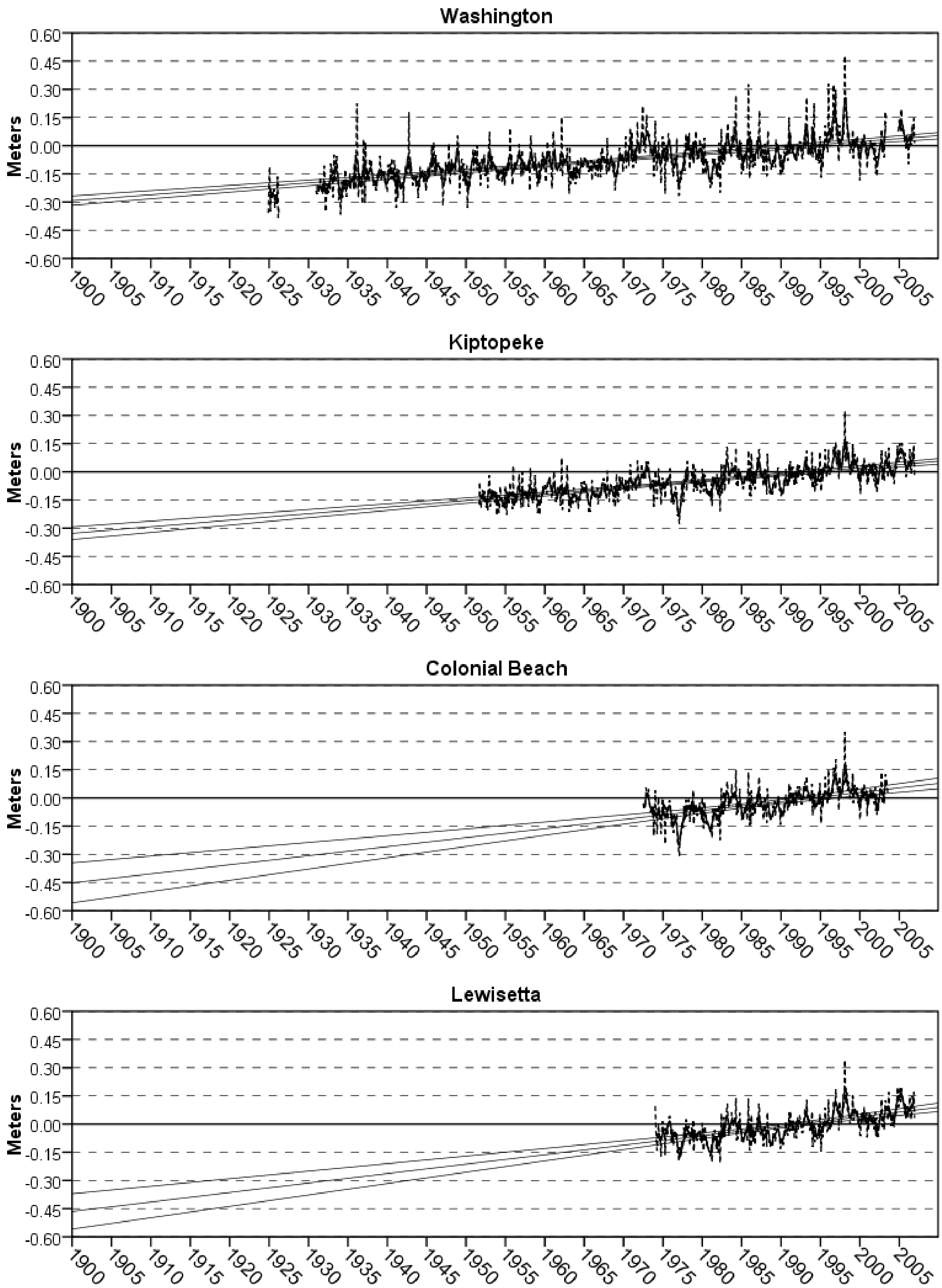

Cambridge
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

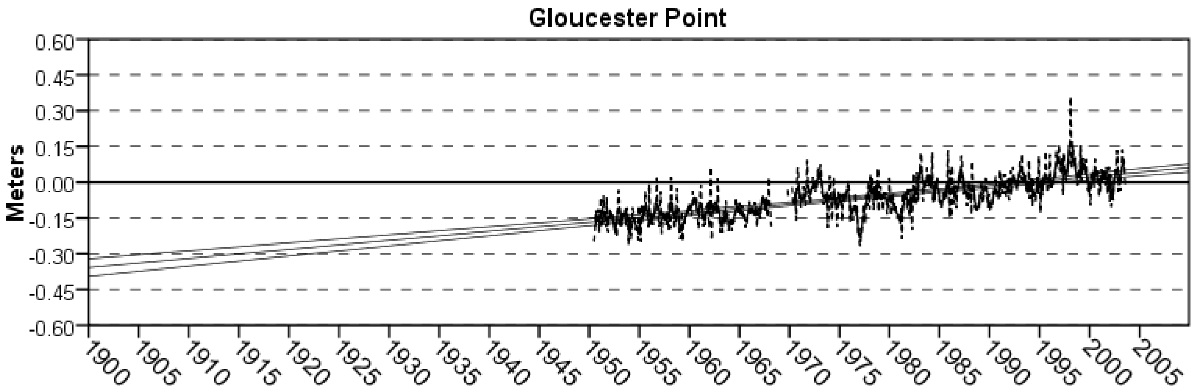

Chesapeake City
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

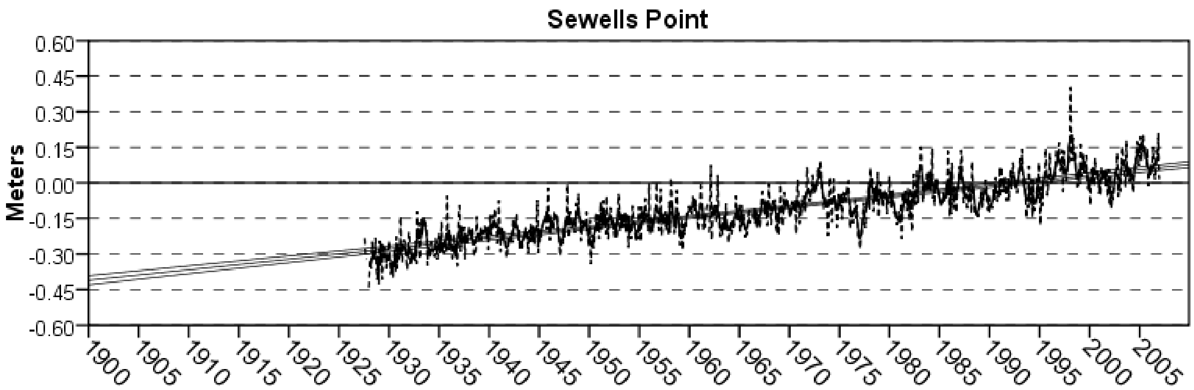

Baltimore
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

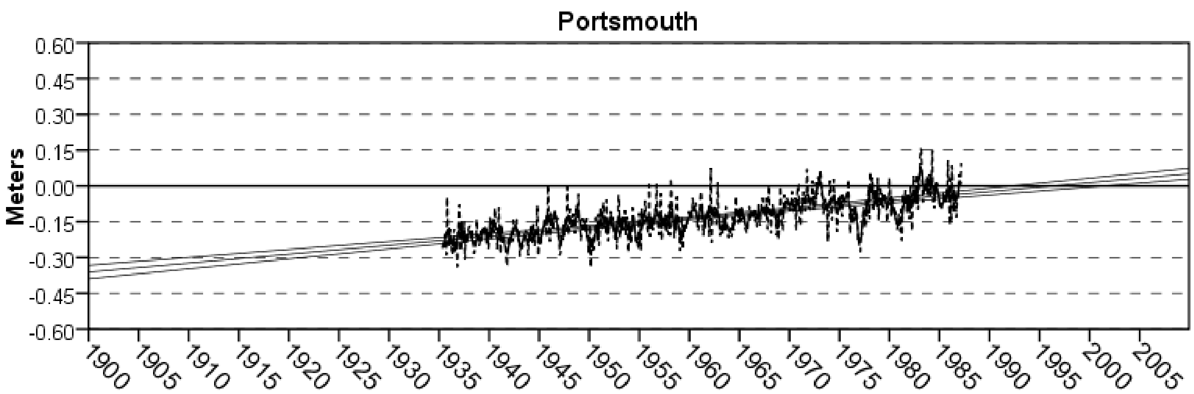

Annapolis
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

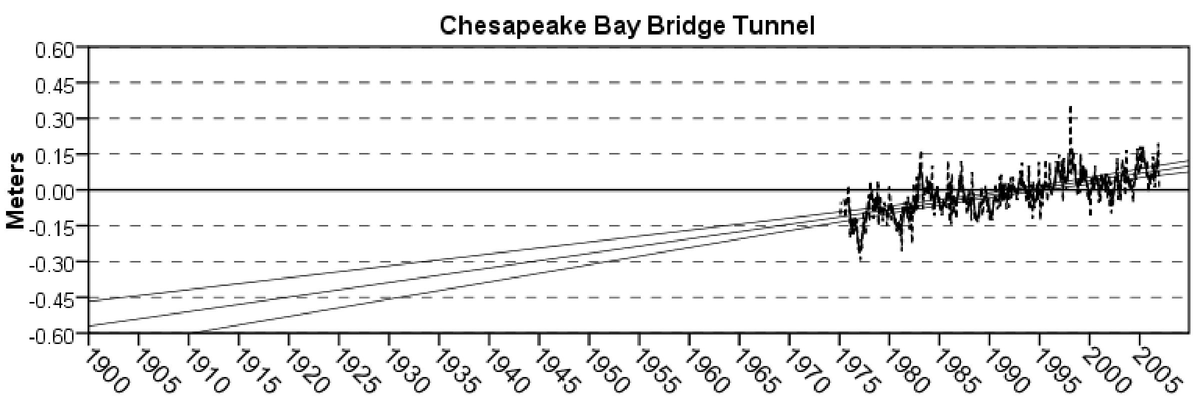

Solomons Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

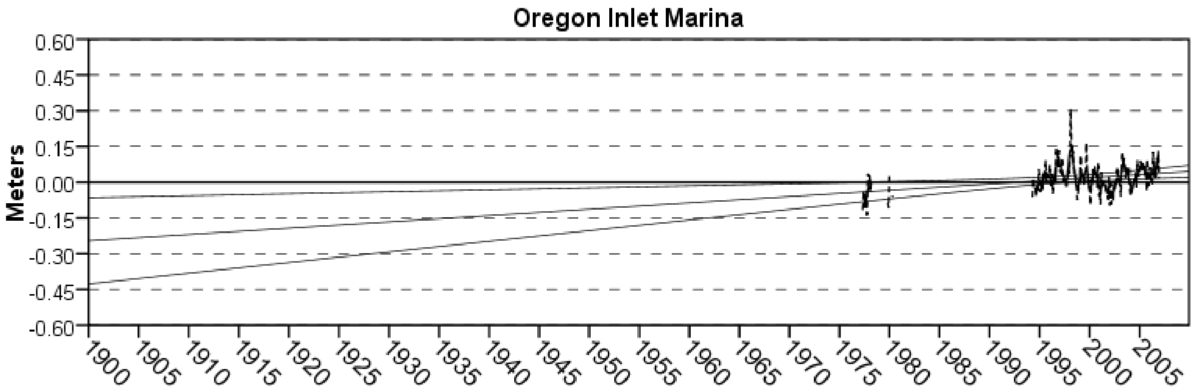

Washington
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Kiptopeke
Colonial Beach
Lewisetta


Gloucester Point
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Sewells Point
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Portsmouth
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Chesapeake Bay Bridge Tunnel
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Oregon Inlet Marina
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
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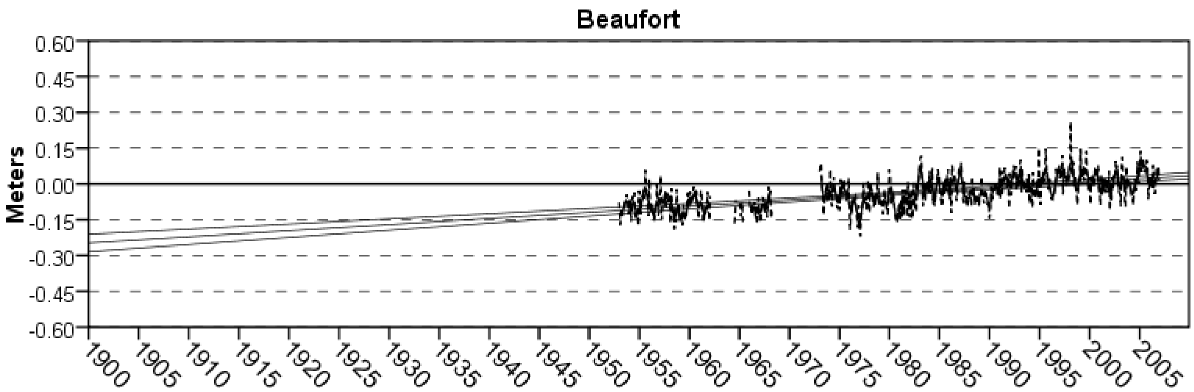
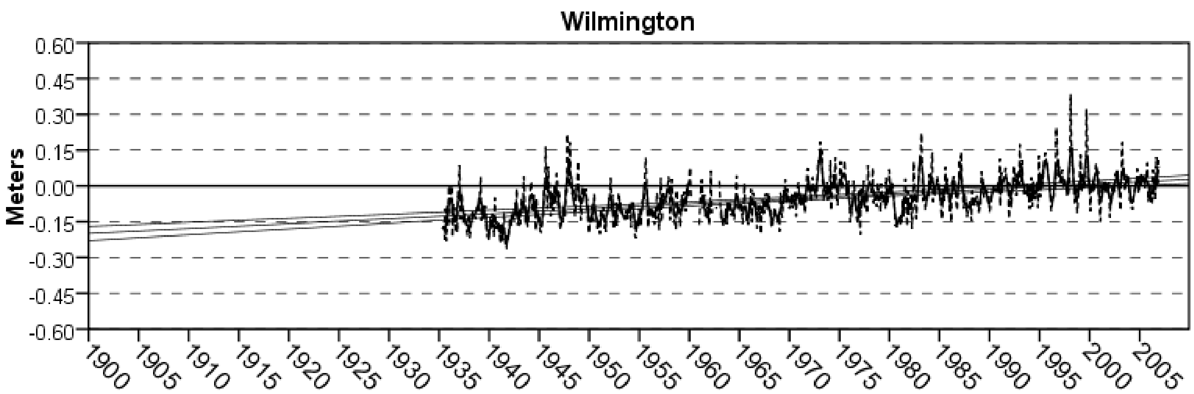
1985
1990
1995
2000
2005


Beaufort
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Wilmington
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
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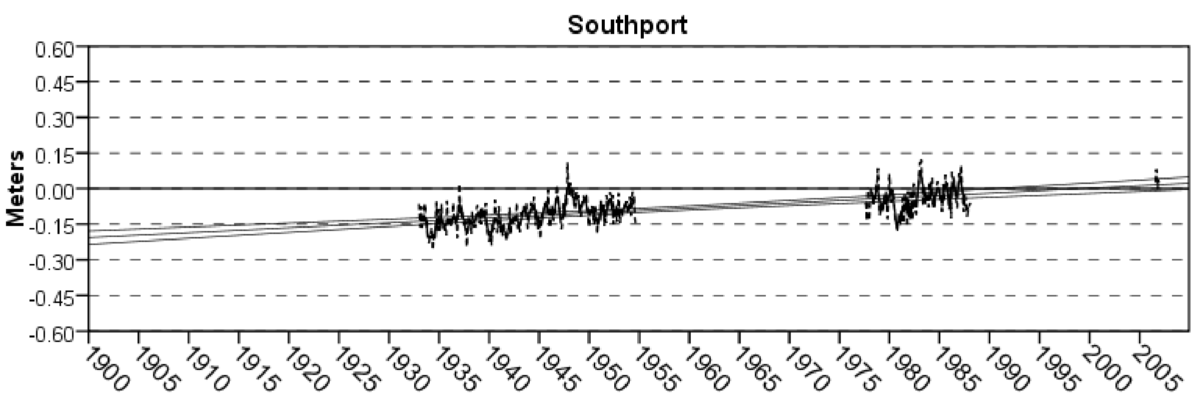
1985
1990
1995
2000
2005


Southport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
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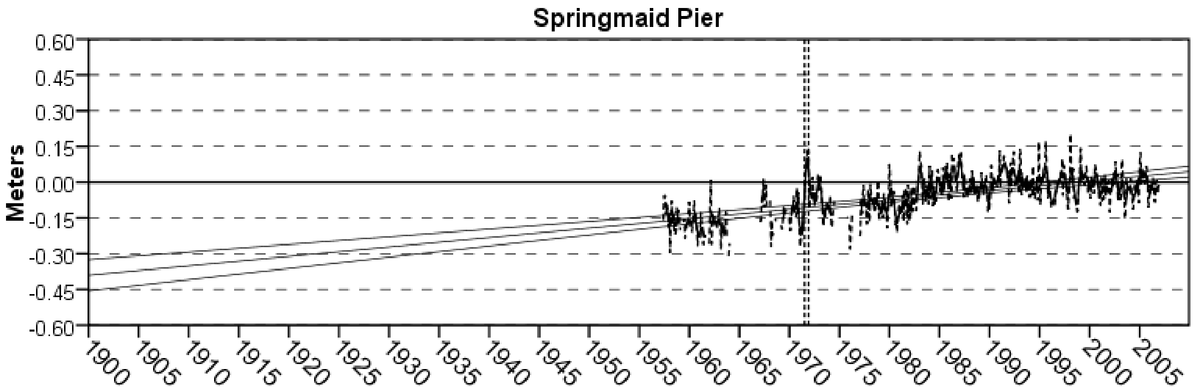
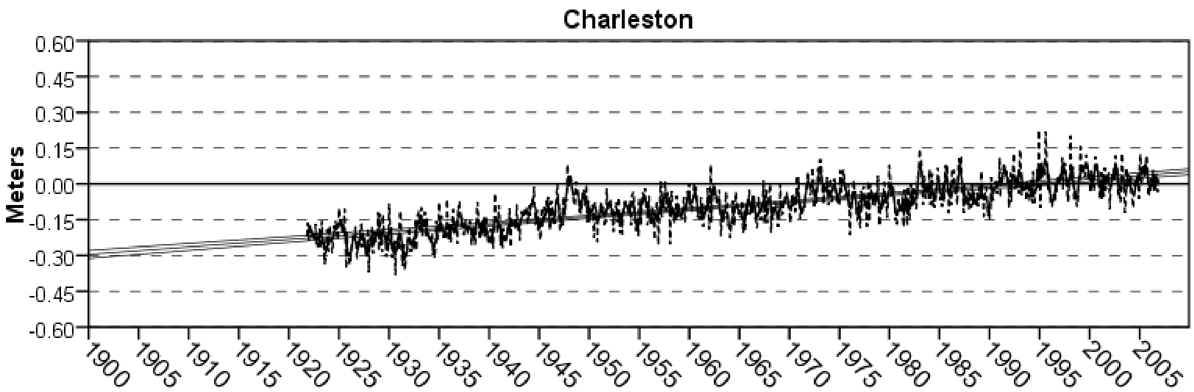
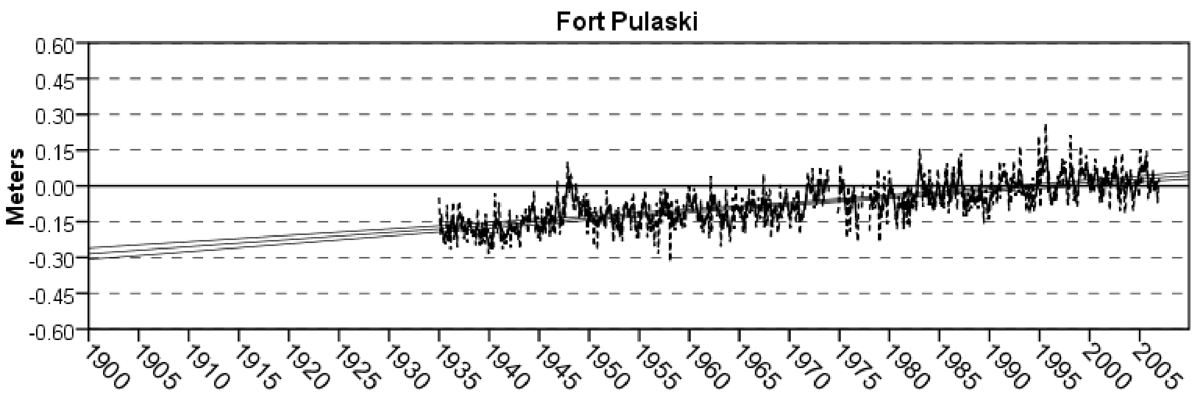
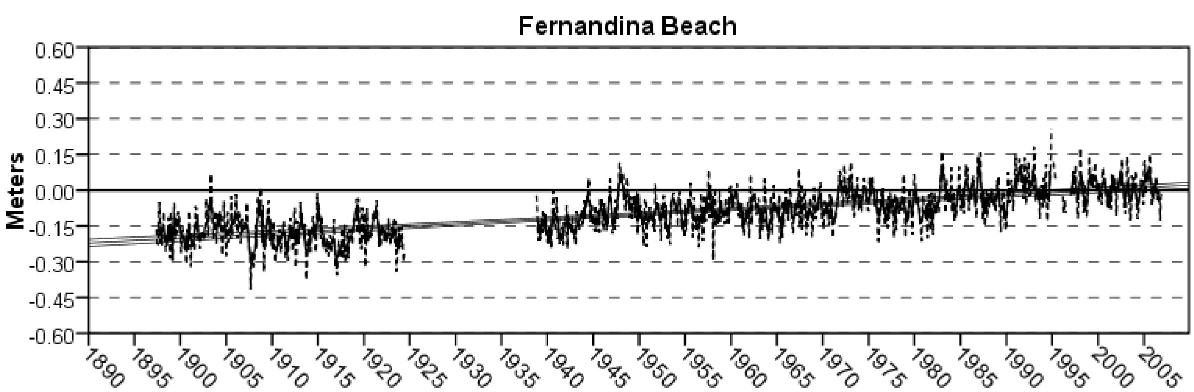
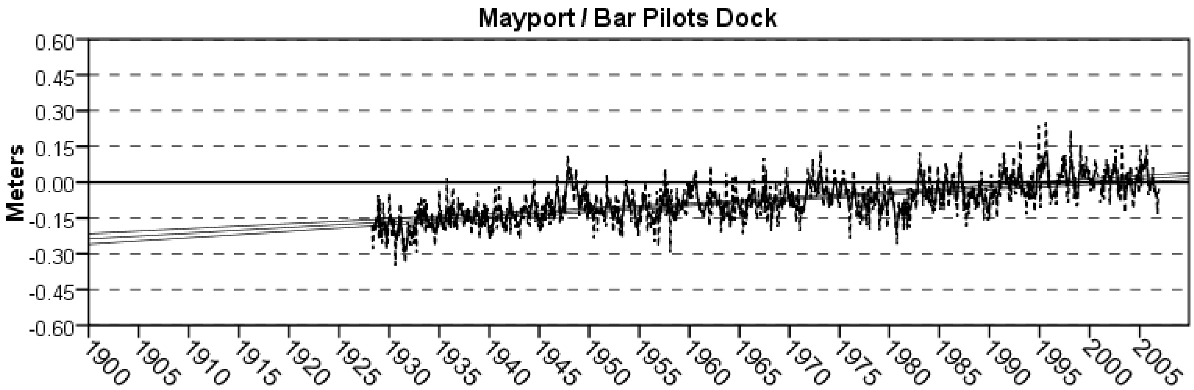
1985
1990
1995
2000
2005

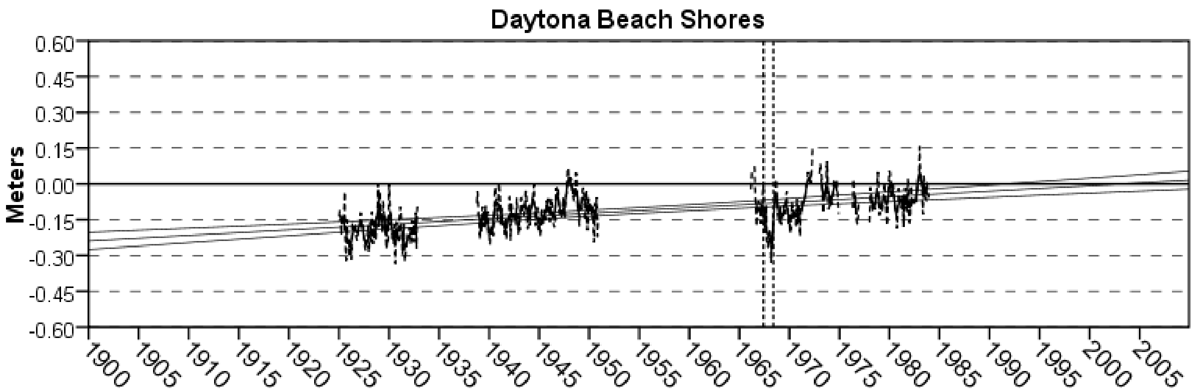

Springmaid Pier
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

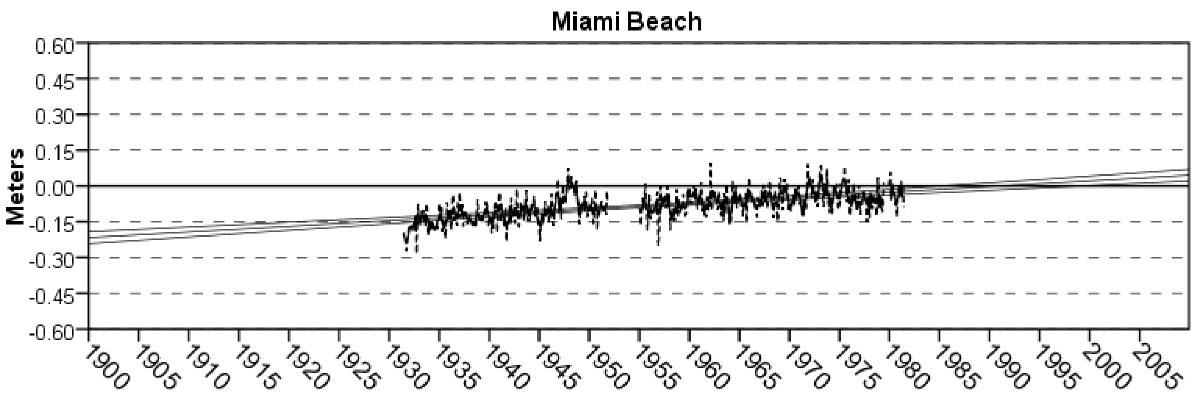

Charleston
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

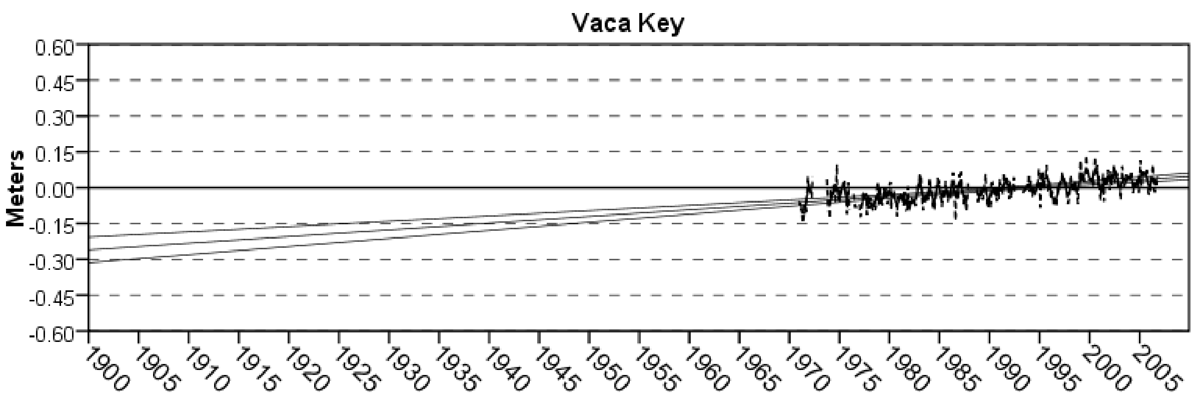

Fort Pulaski
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Fernandina Beach
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

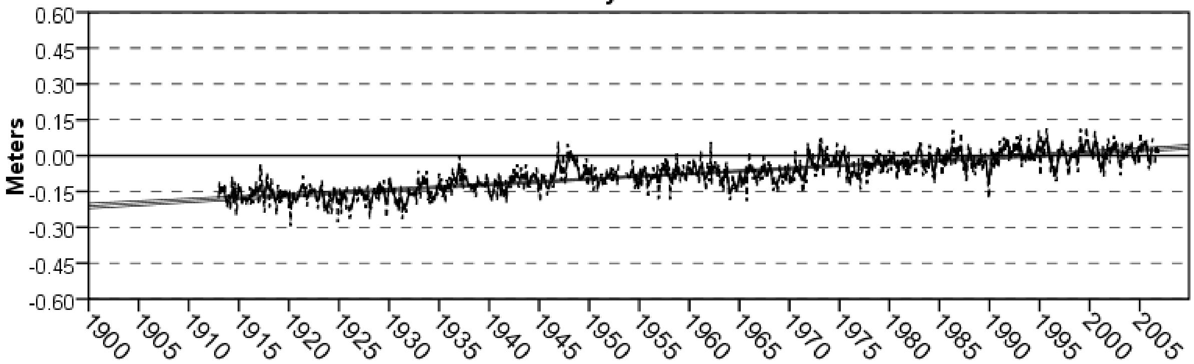

Mayport / Bar Pilots Dock
Meters


Daytona Beach Shores
Meters

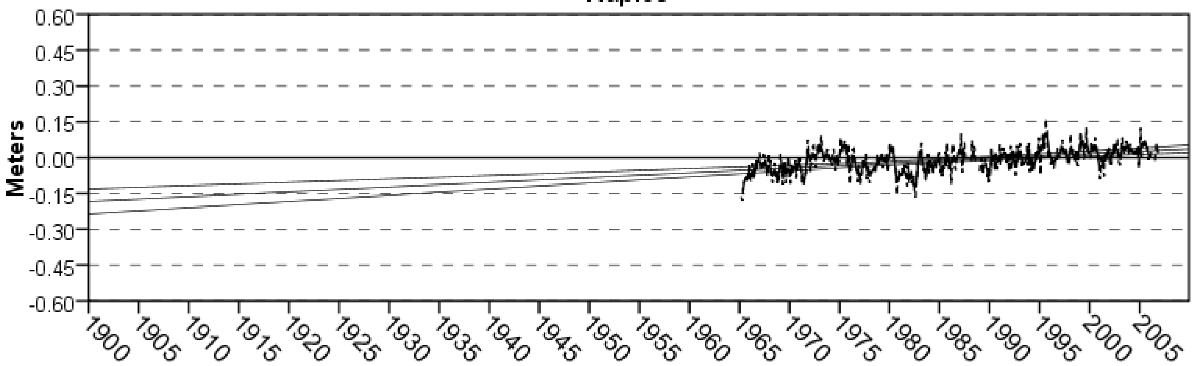

Miami Beach
Meters


Vaca Key
Meters

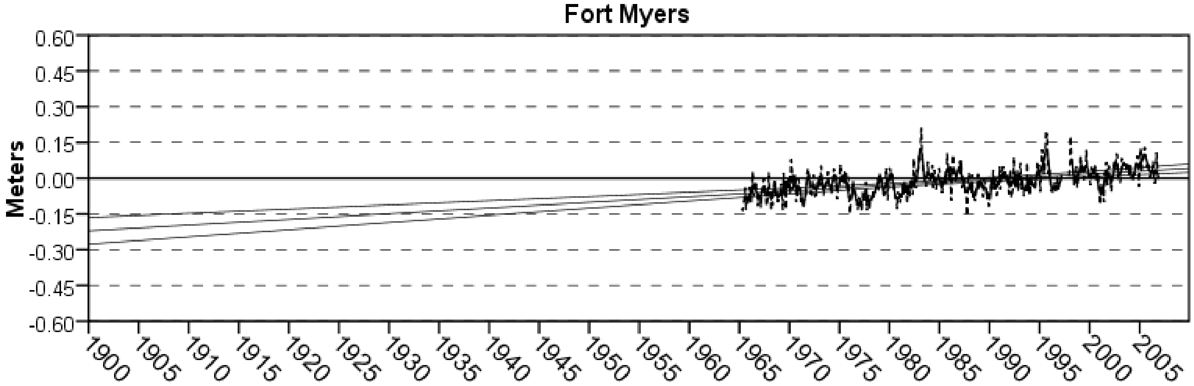
Key West



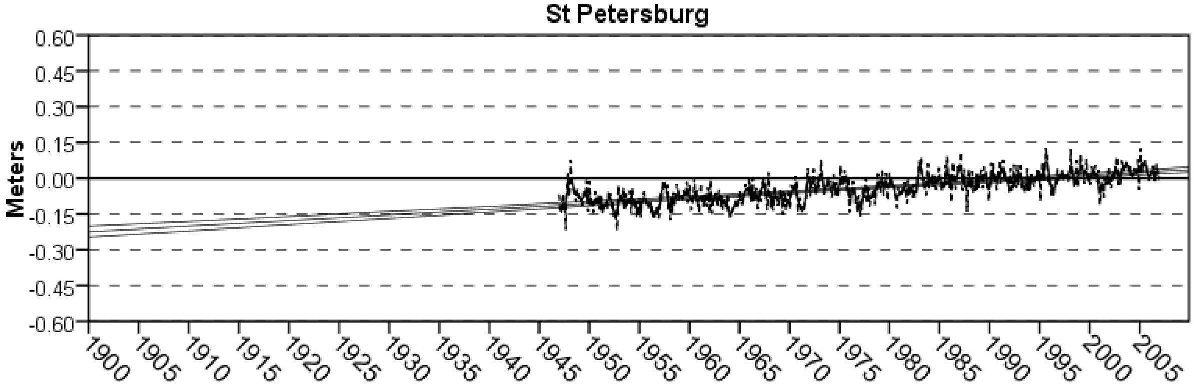
Naples

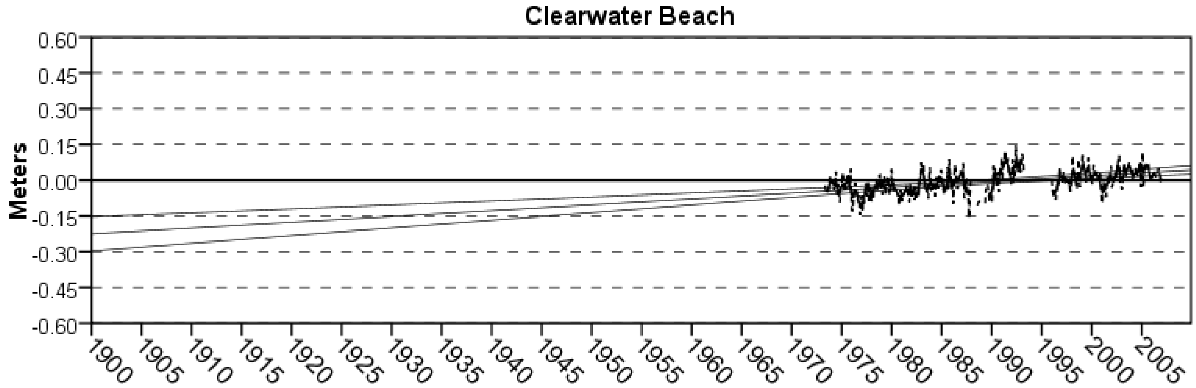


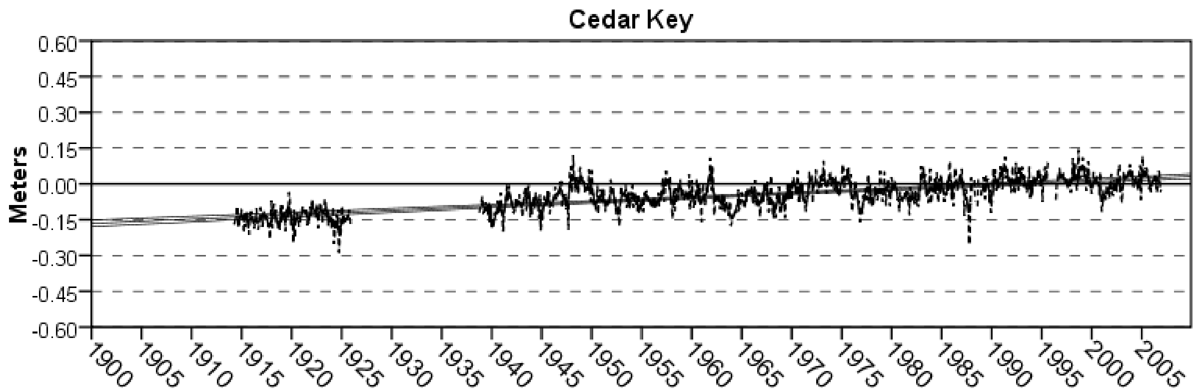
Fort Myers

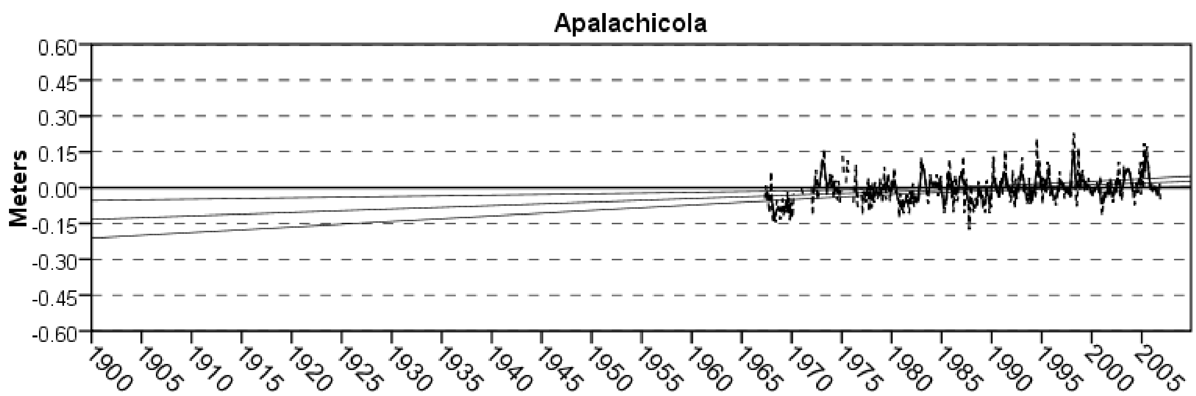


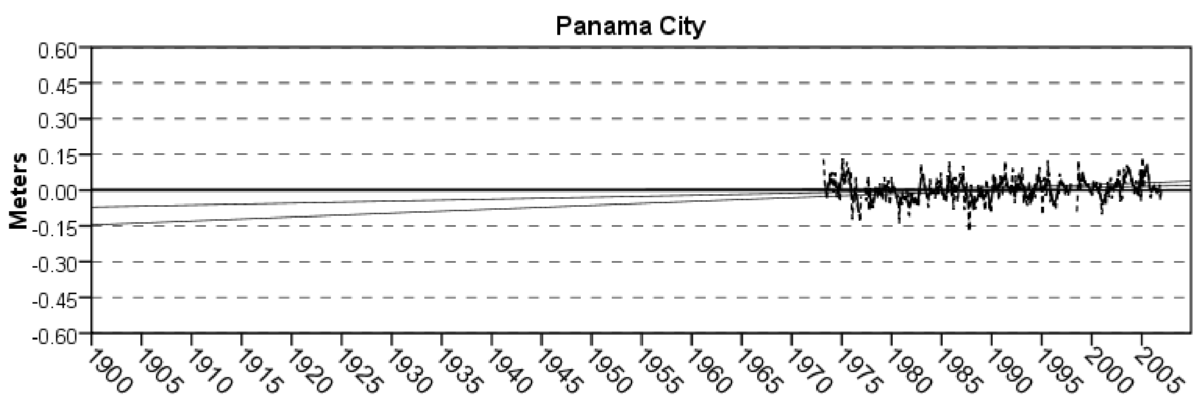
St Petersburg

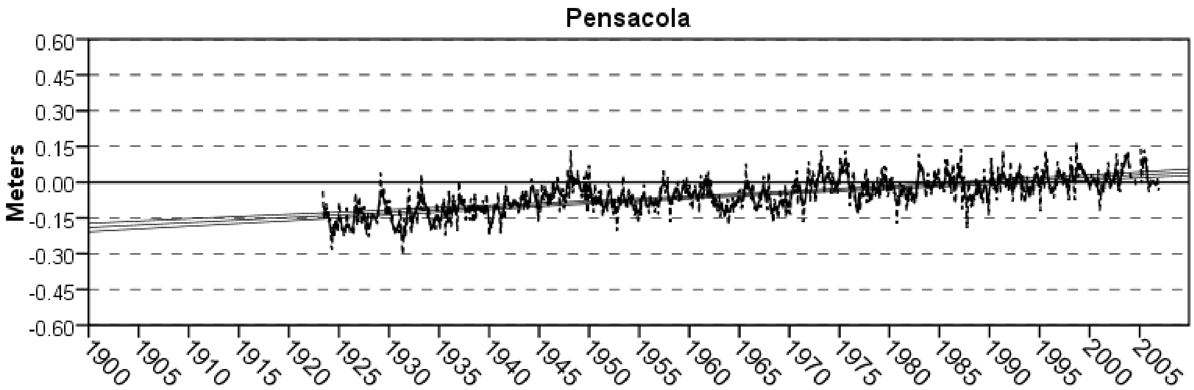


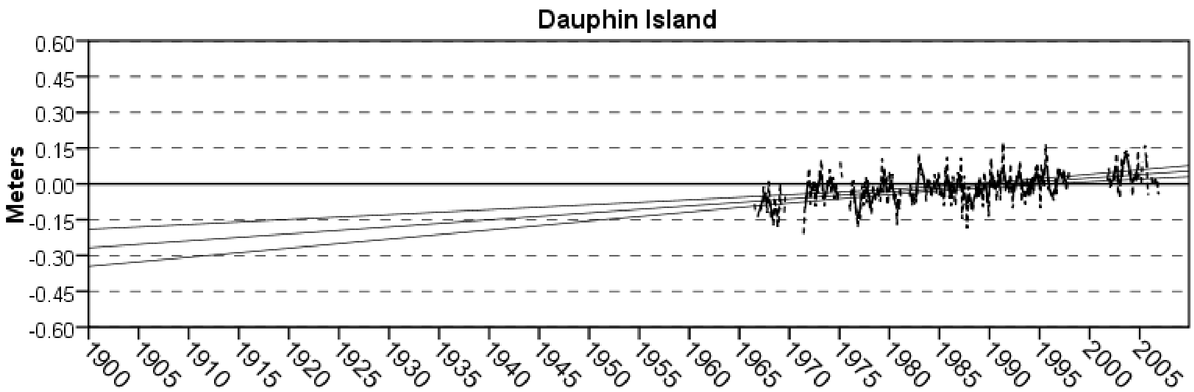

Clearwater Beach
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

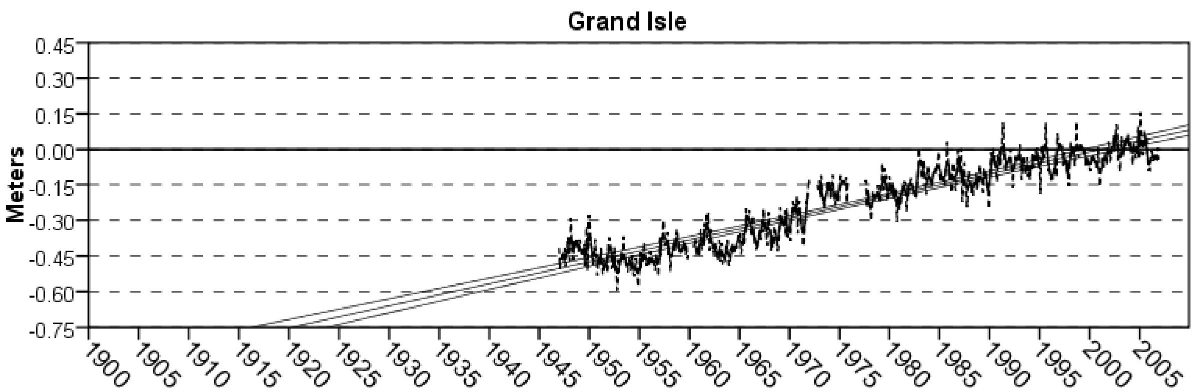

Cedar Key
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

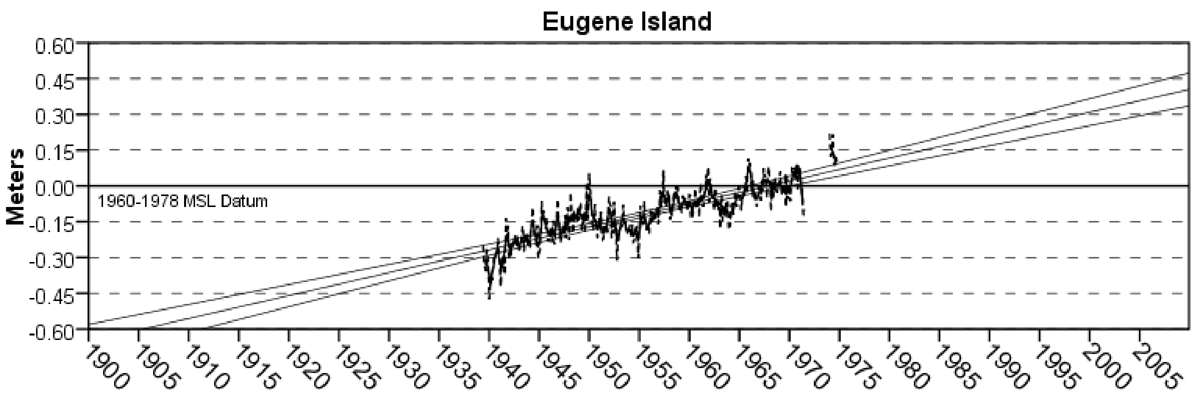

Apalachicola
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

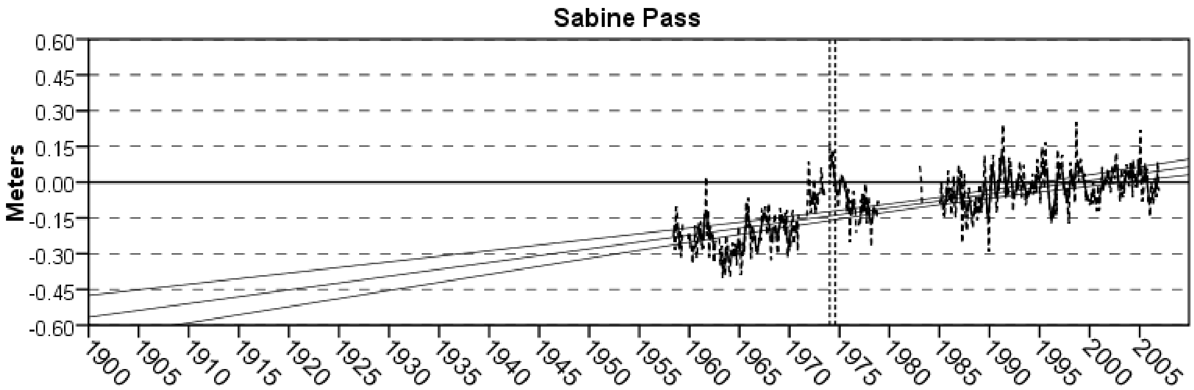

Panama City
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

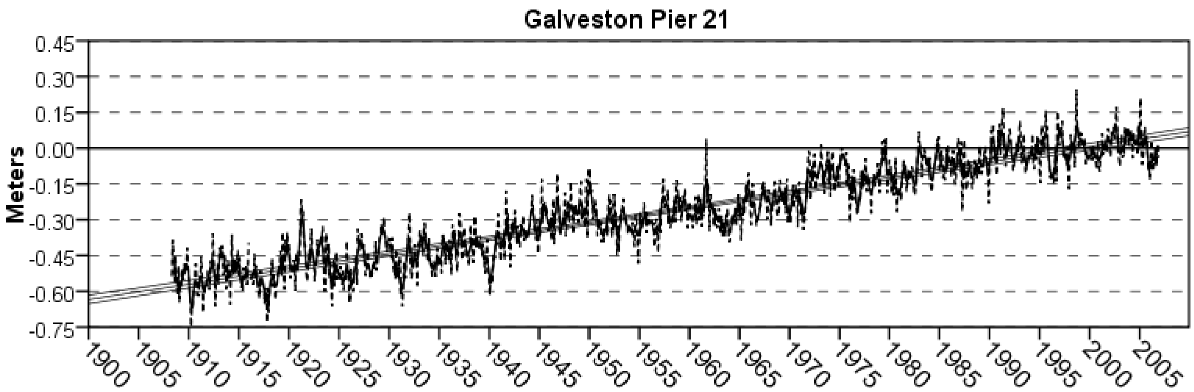

Pensacola
Meters
0.60 0.45 0.30 0.15 0.00 -0.15 -0.30 -0.45 -0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

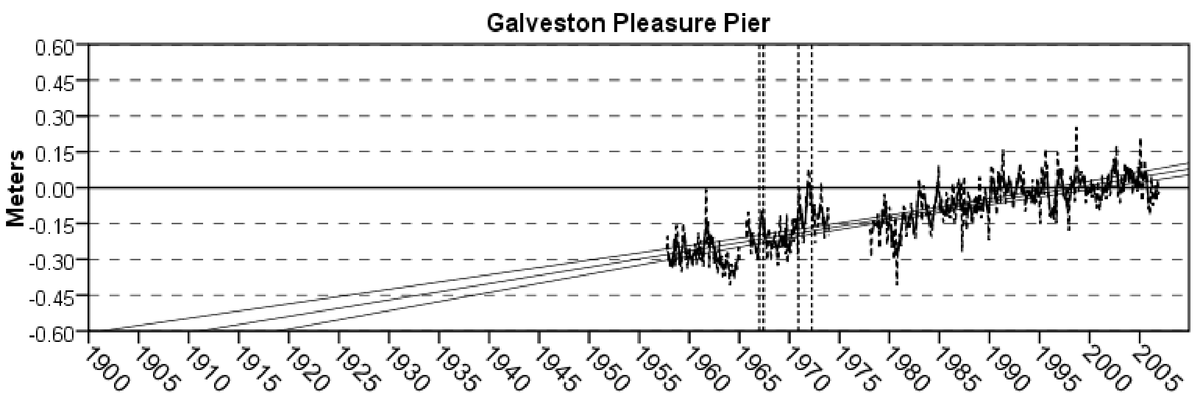

Dauphin Island
Meters
0.60 0.45 0.30 0.15 0.00 -0.15 -0.30 -0.45 -0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

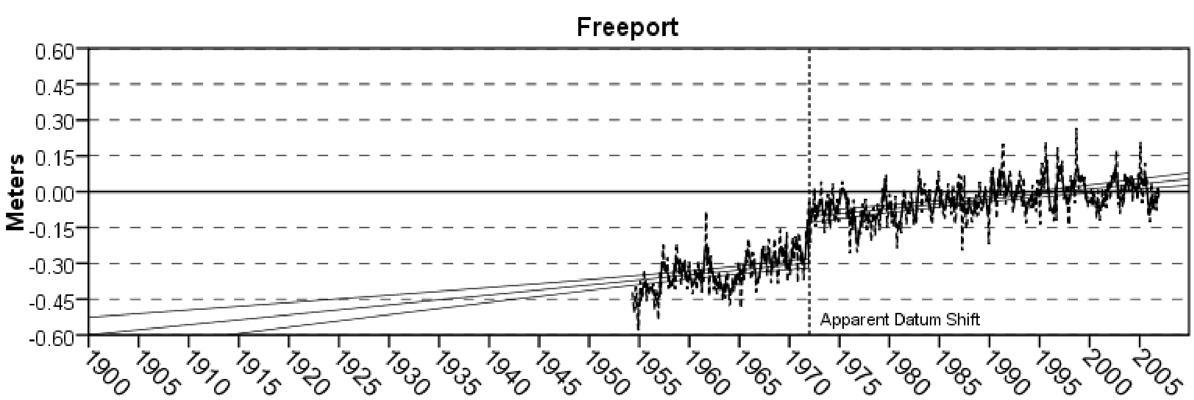

Grand Isle
Meters
0.45 0.30 0.15 0.00 -0.15 -0.30 -0.45 -0.60 -0.75
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

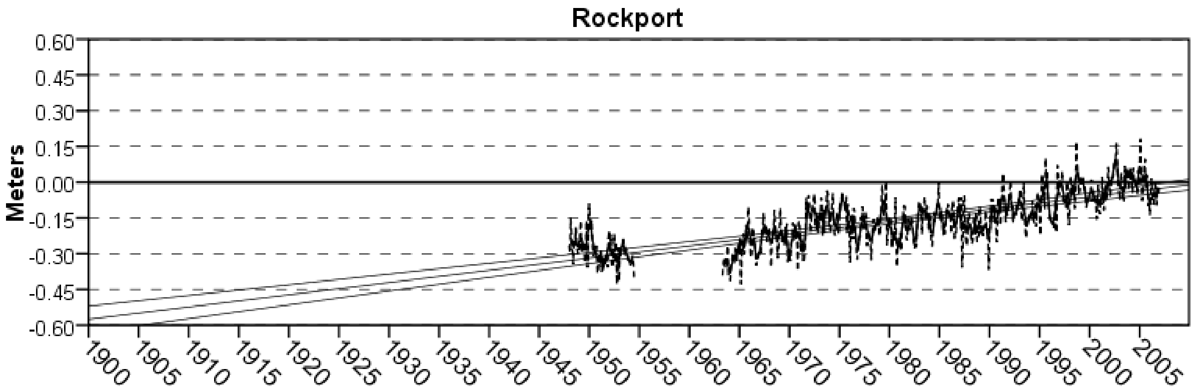

Eugene Island
Meters
1960-1978 MSL Datum
0.60 0.45 0.30 0.15 0.00 -0.15 -0.30 -0.45 -0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Sabine Pass
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

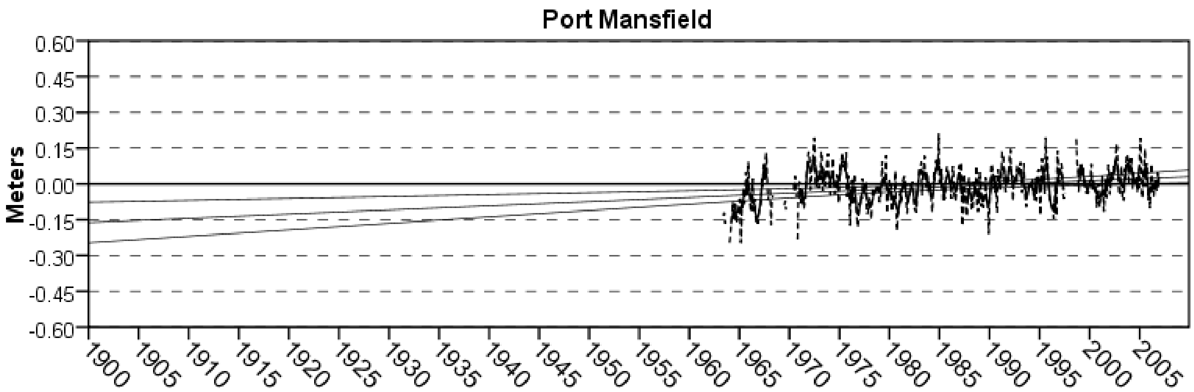

Galveston Pier 21
Meters
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Galveston Pleasure Pier
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

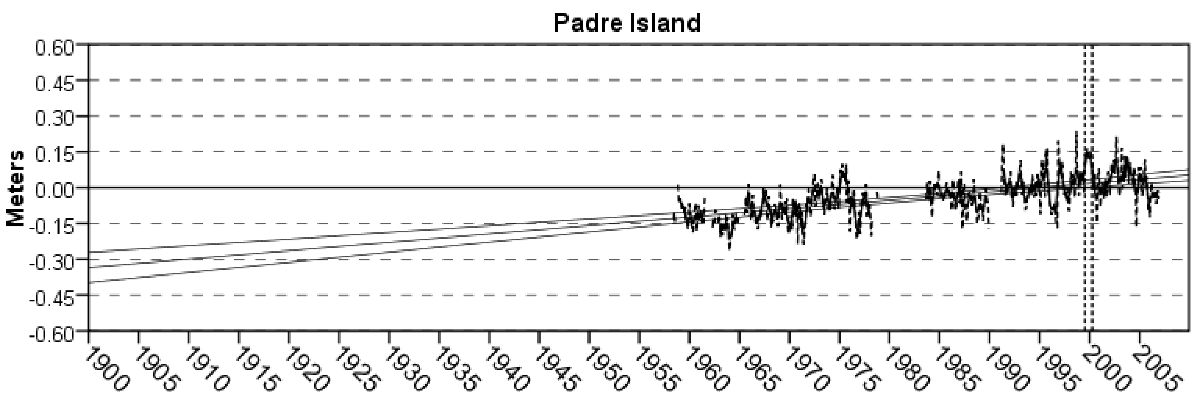

Freeport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
Apparent Datum Shift
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005



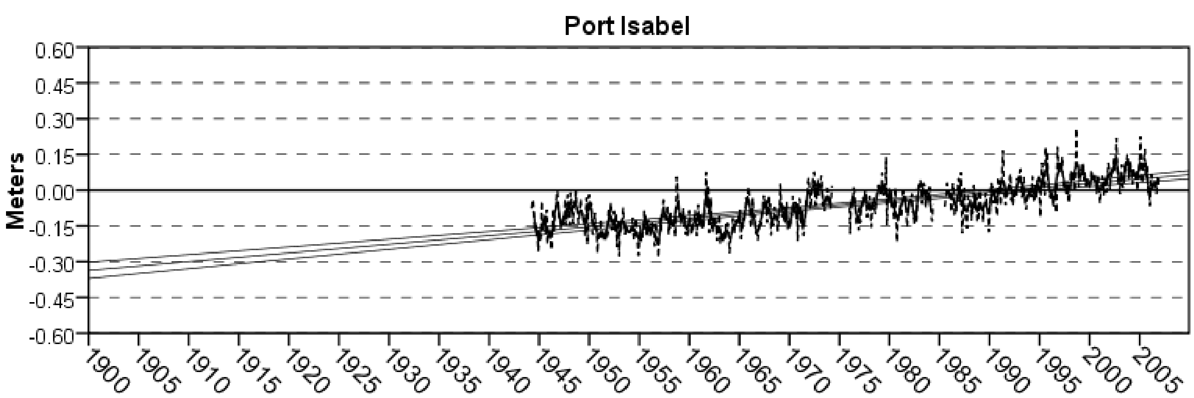
Rockport
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005



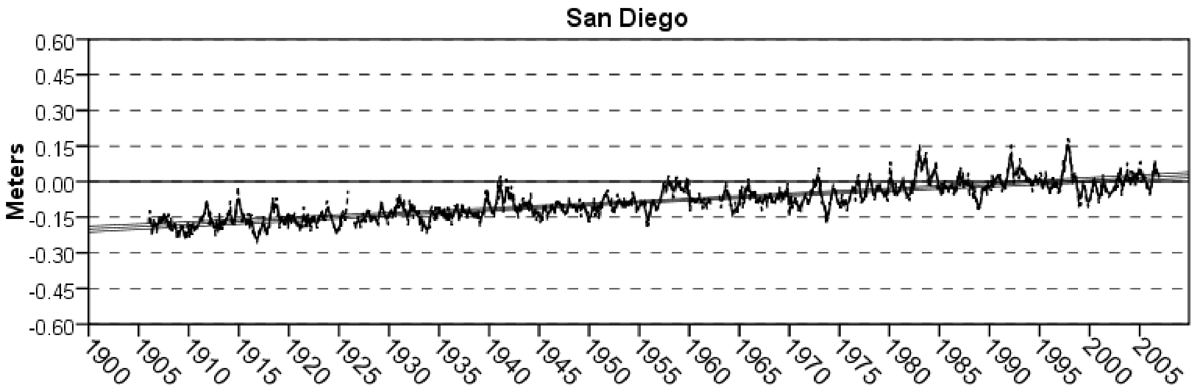
Port Mansfield
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

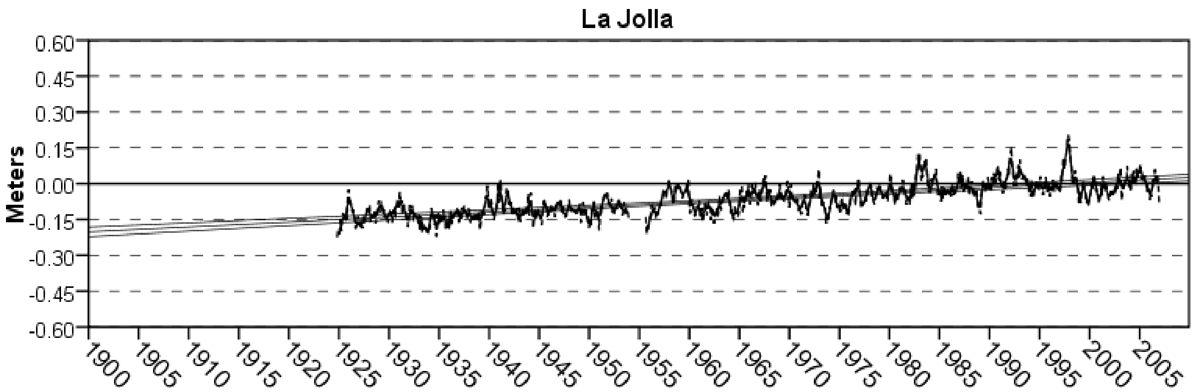


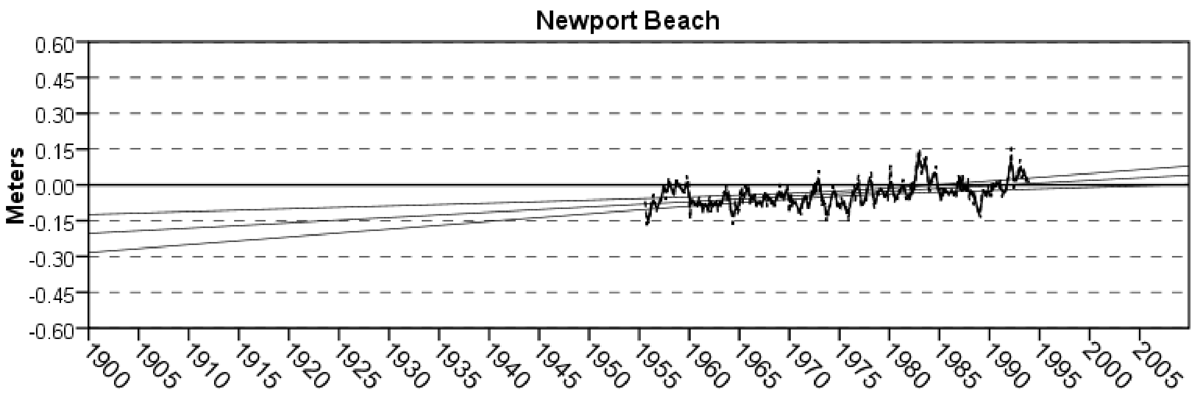
Padre Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

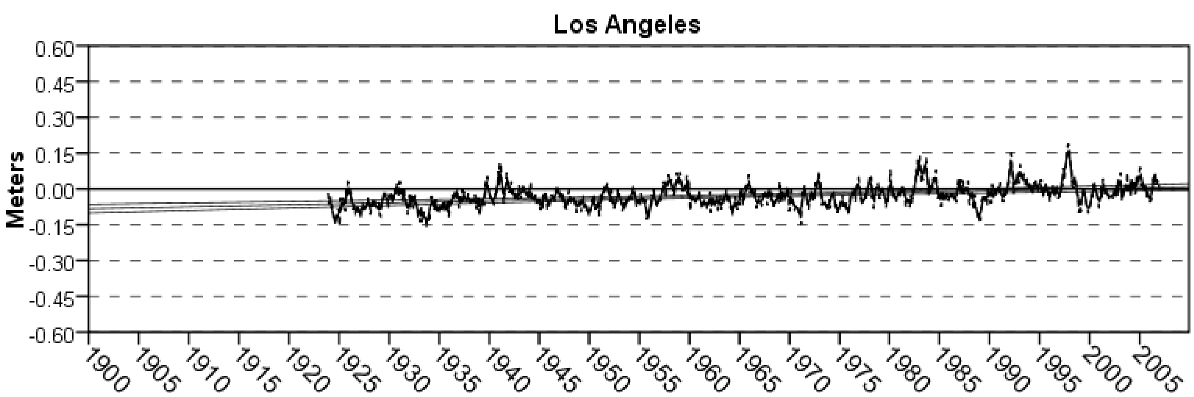


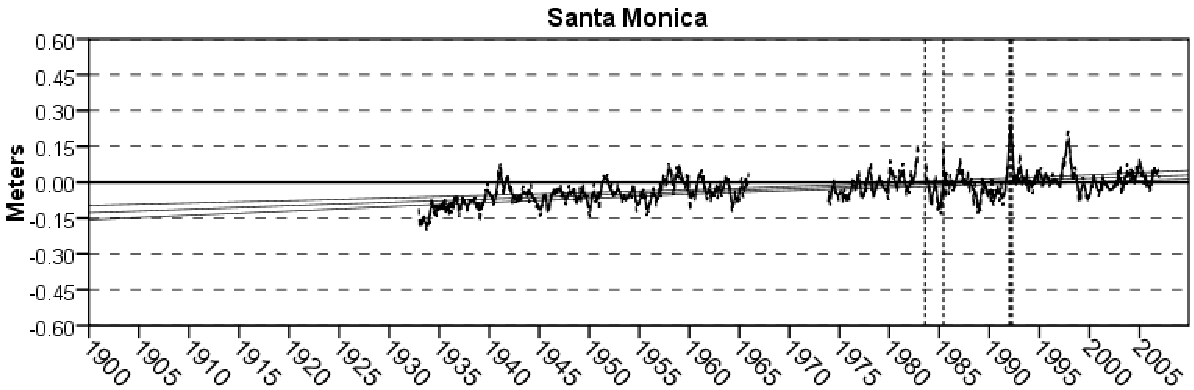
Port Isabel
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

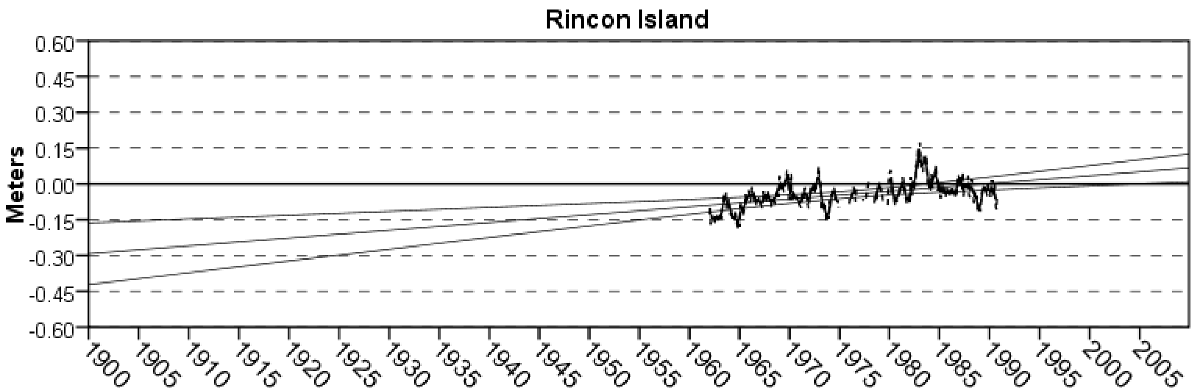

San Diego
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

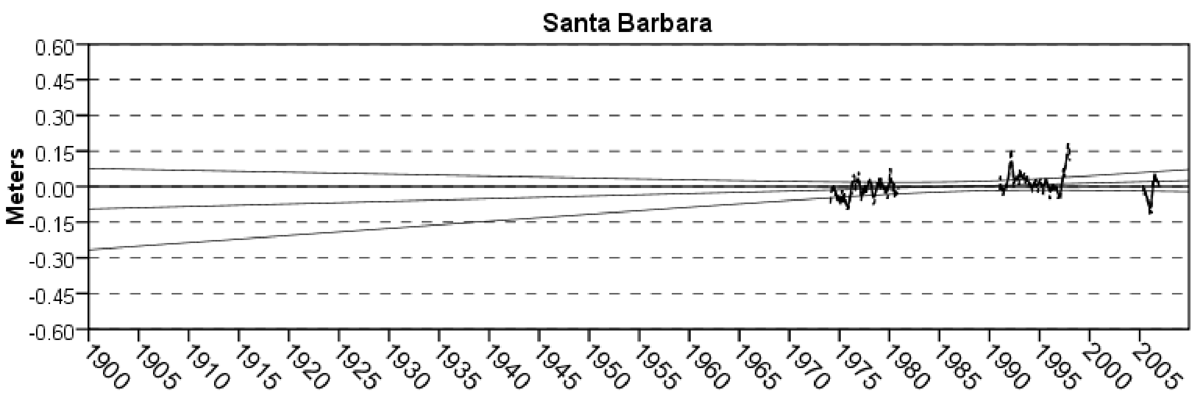

La Jolla
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

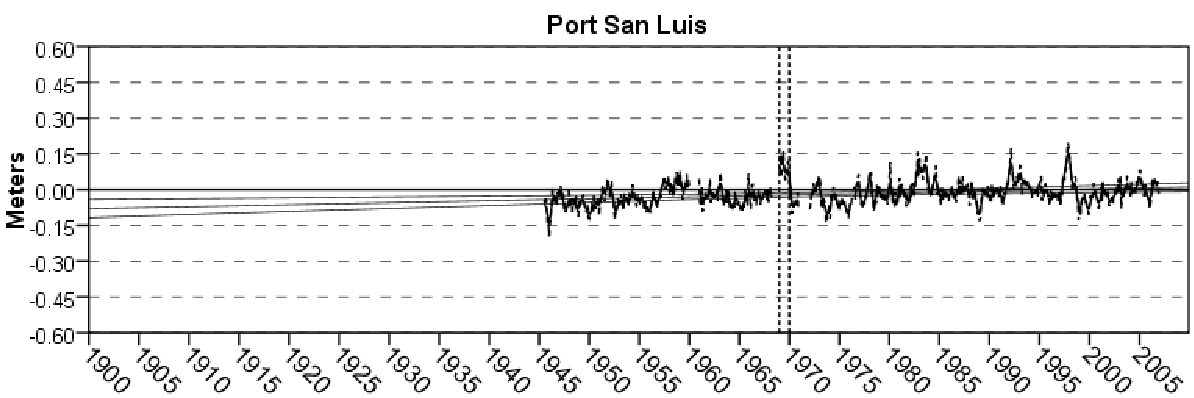

Newport Beach
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Los Angeles
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

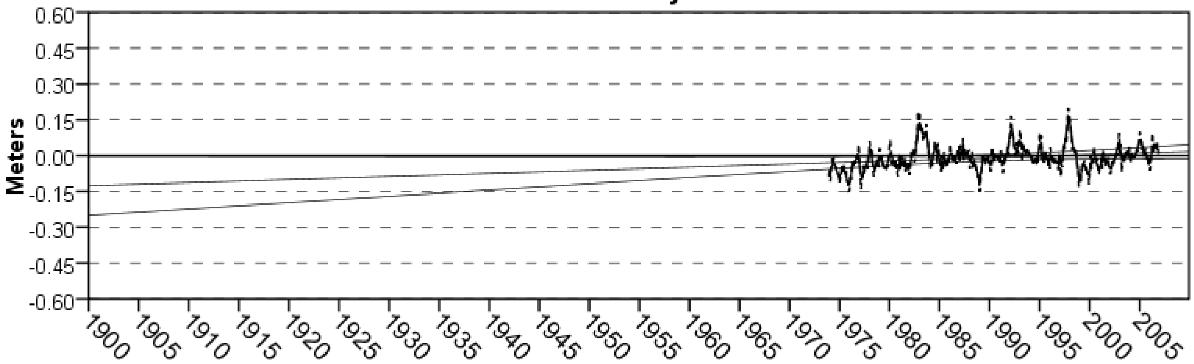

Santa Monica
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Rincon Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

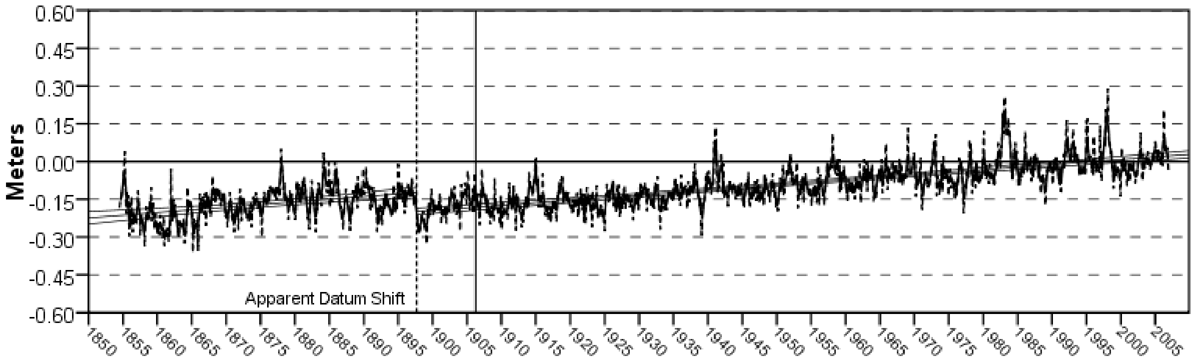

Santa Barbara
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Port San Luis
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

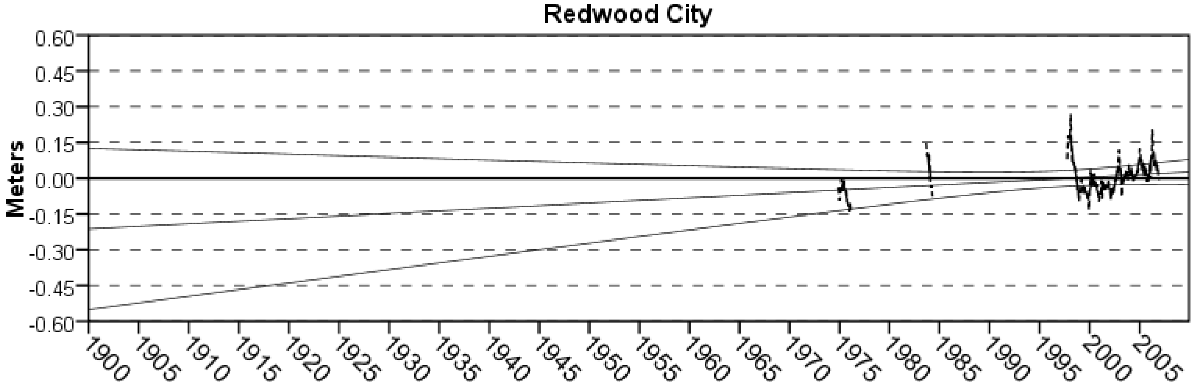
Monterey



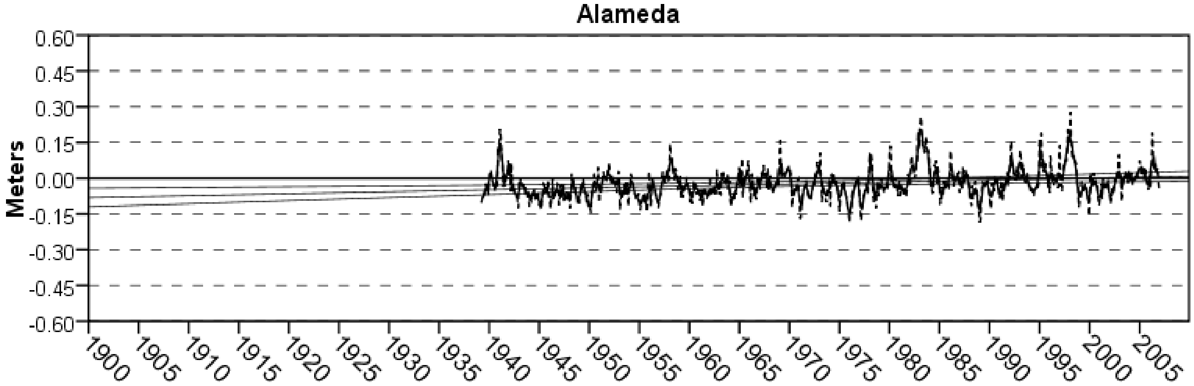
San Francisco

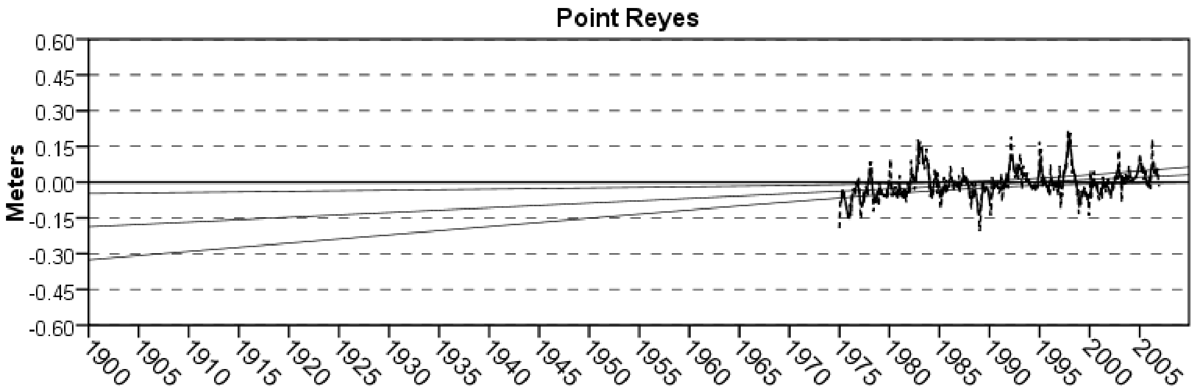


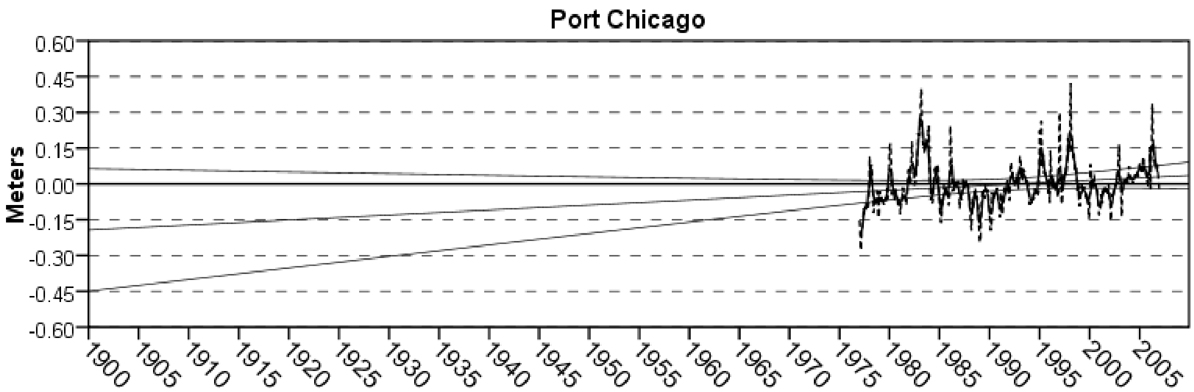
Redwood City

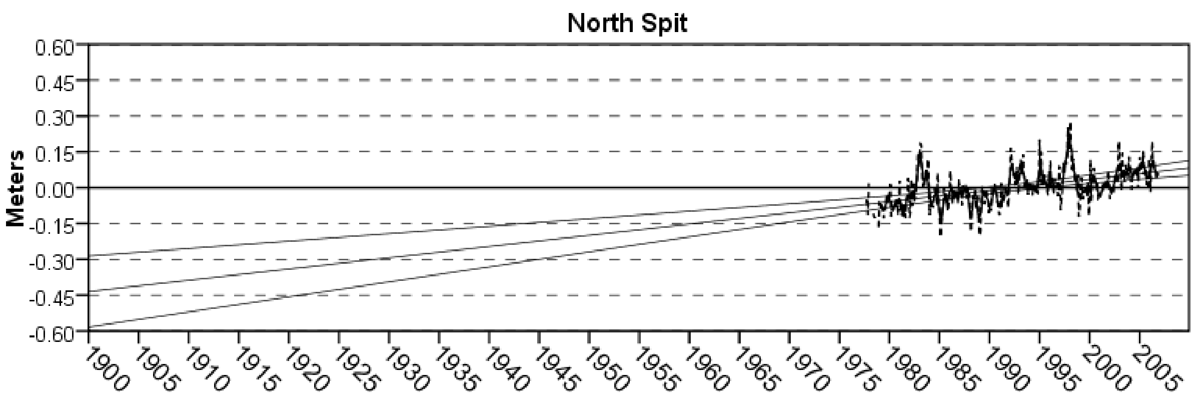


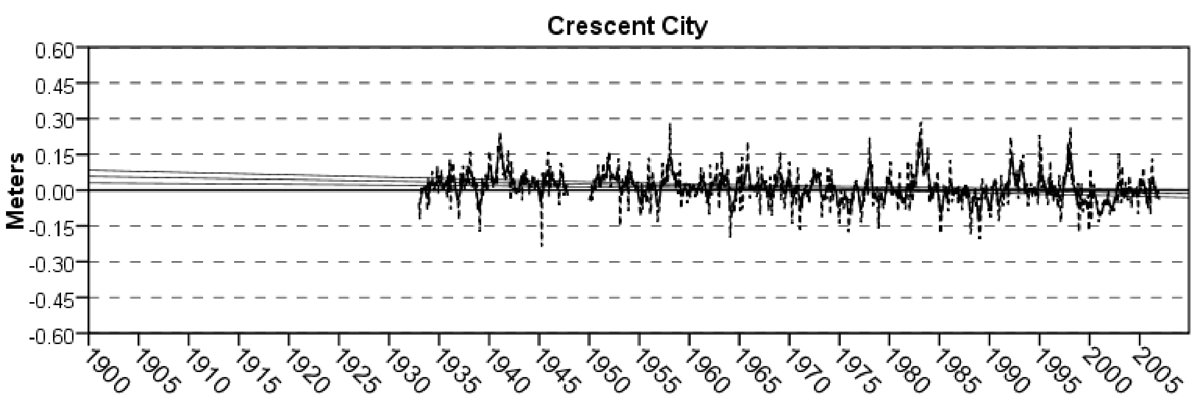
Alameda

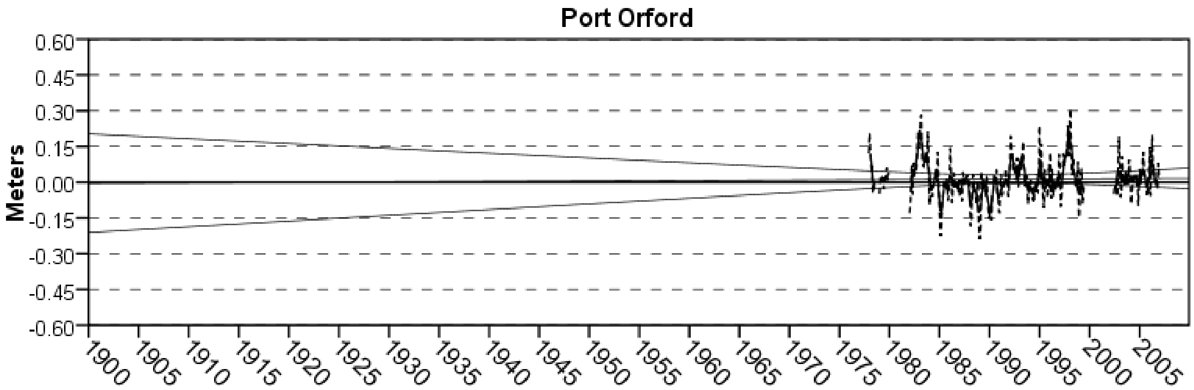


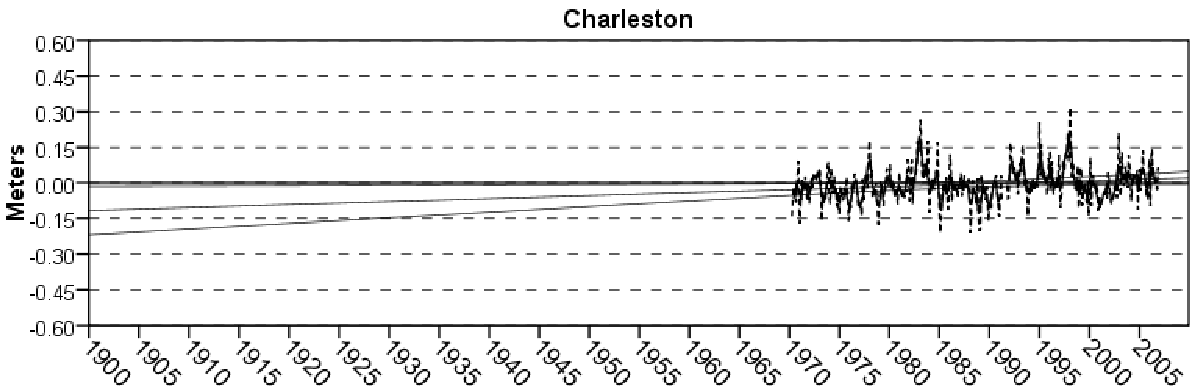

Point Reyes
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

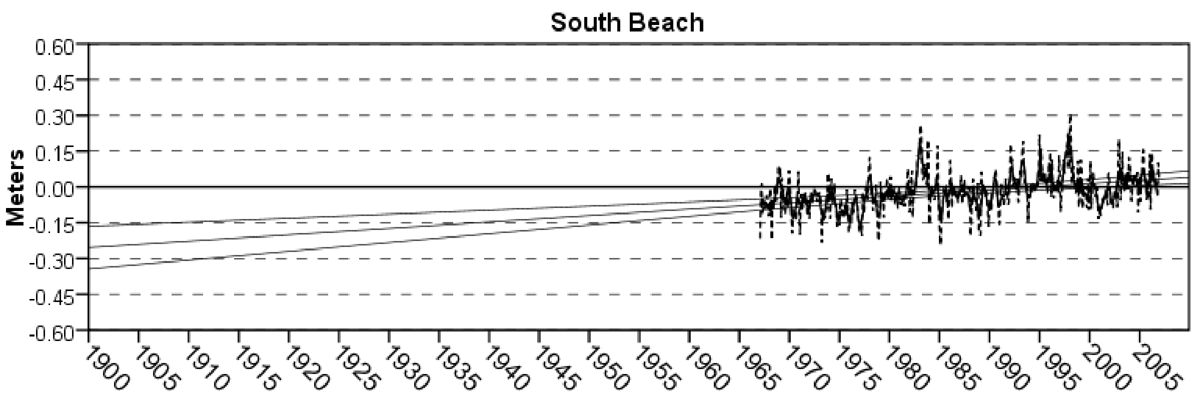

Port Chicago
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

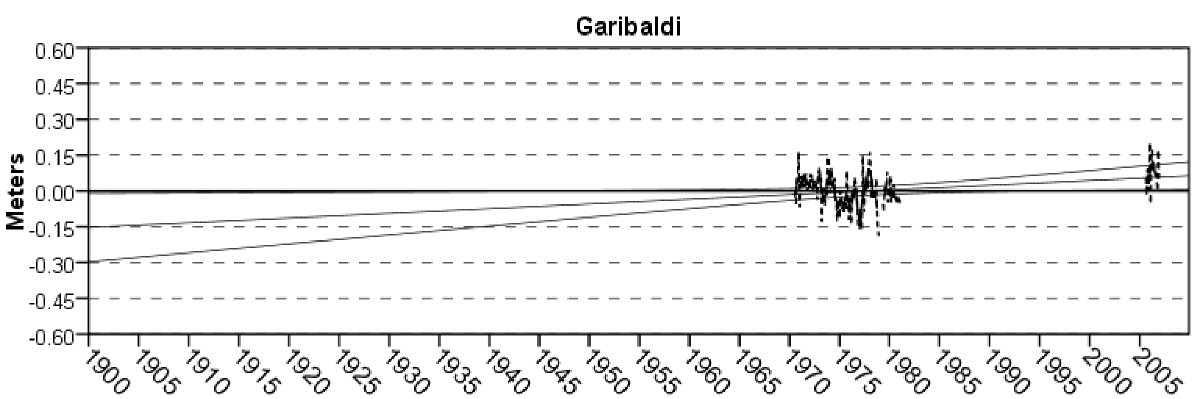

North Spit
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

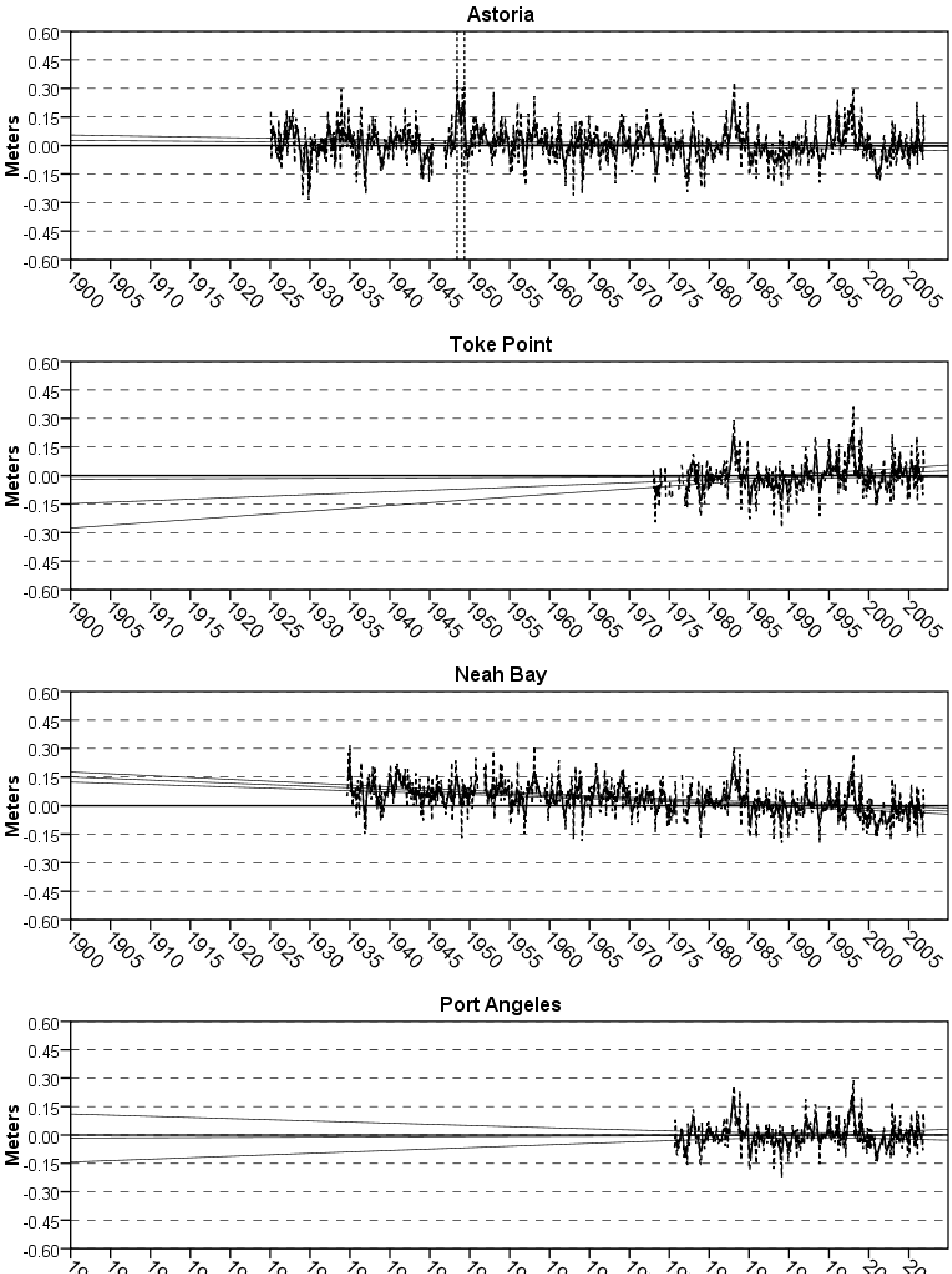

Crescent City
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Port Orford
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

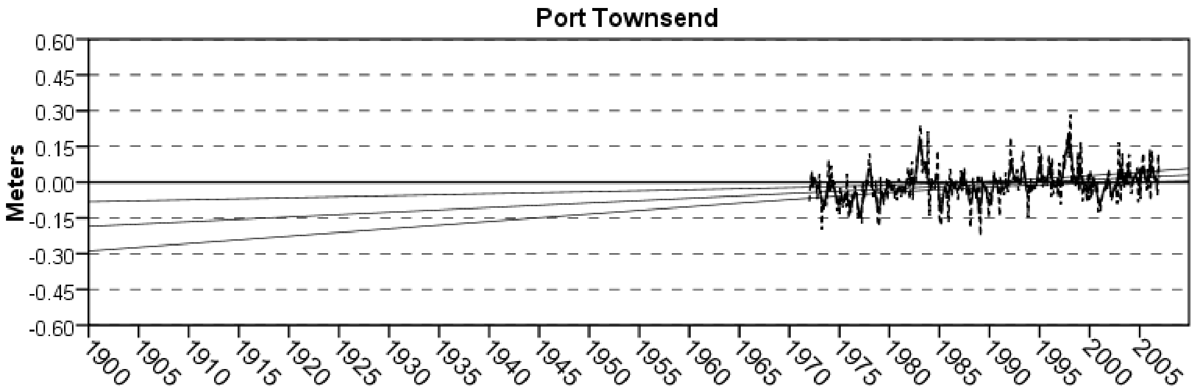

Charleston
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

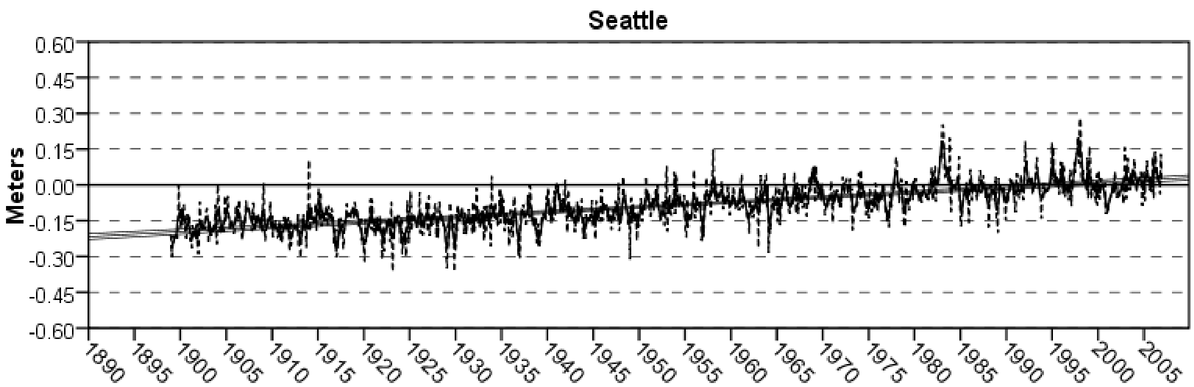

South Beach
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

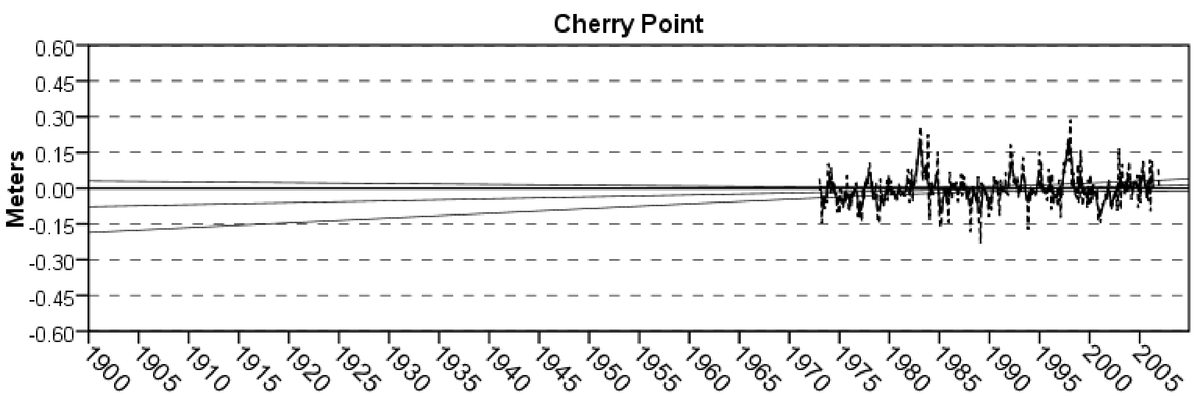

Garibaldi
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

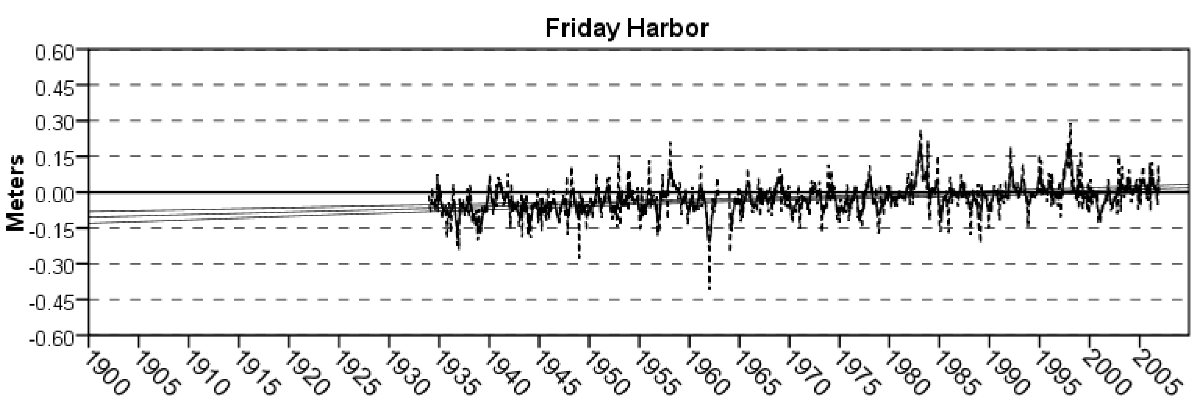


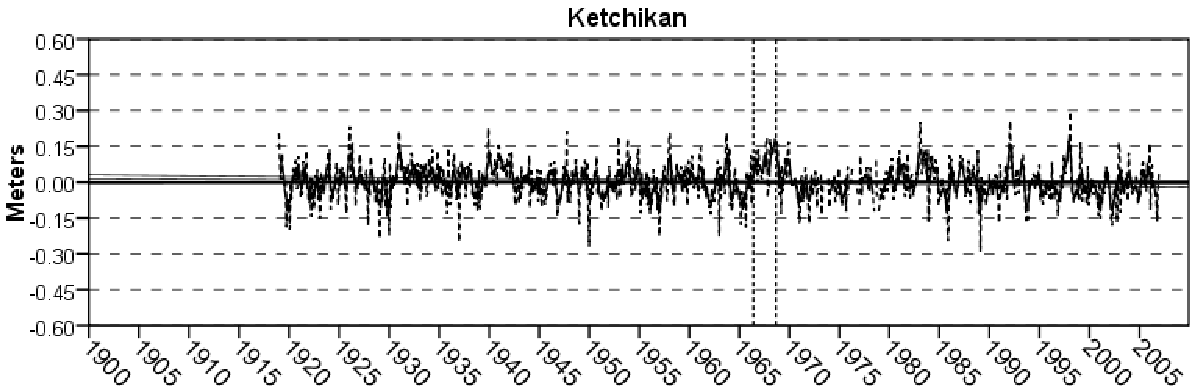
Astoria
Toke Point
Neah Bay
Port Angeles
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

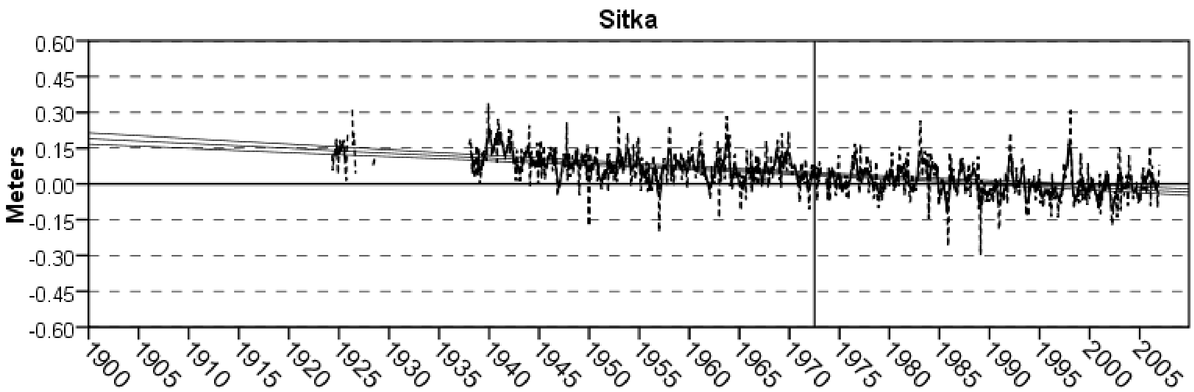

Port Townsend
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

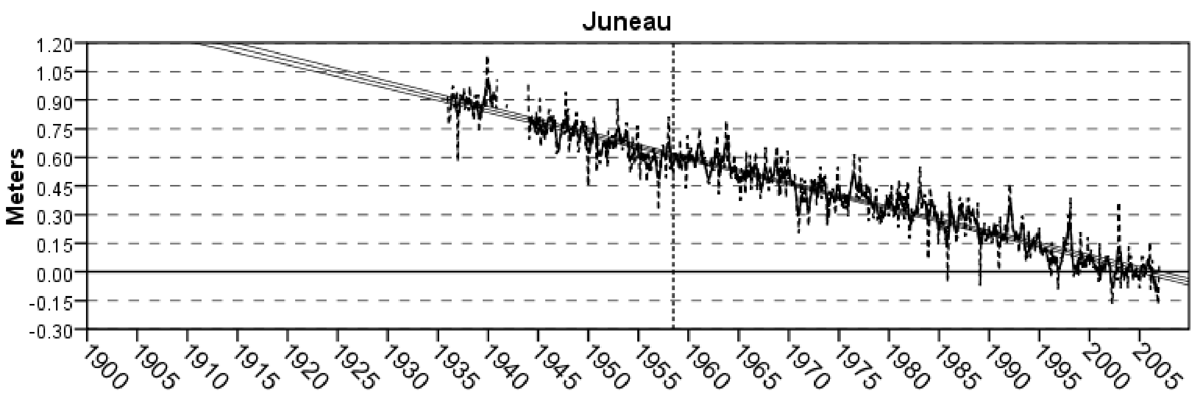

Seattle
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

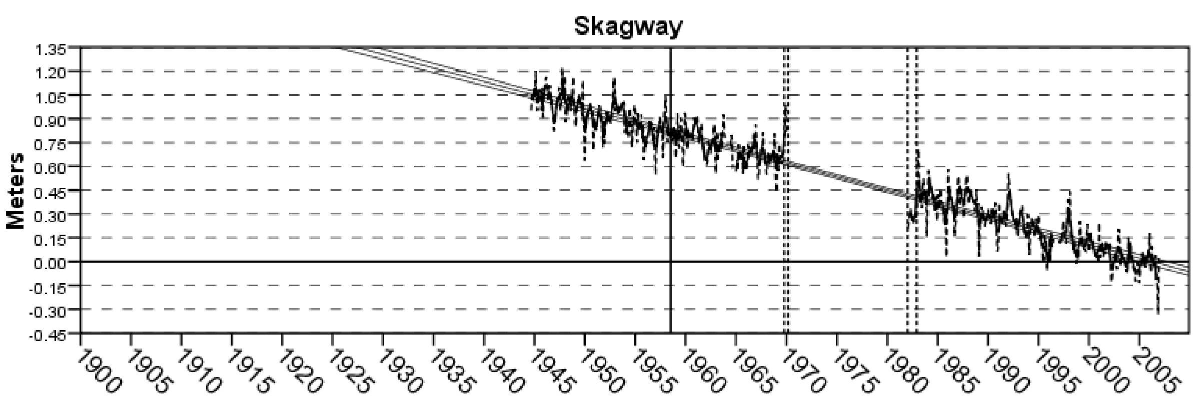

Cherry Point
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

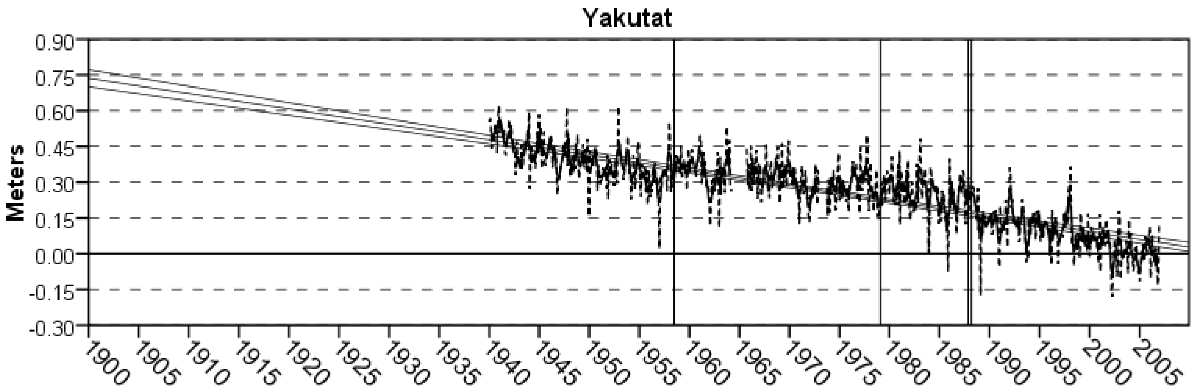

Friday Harbor
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Ketchikan
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Sitka
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Juneau
Meters
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Skagway
Meters
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Yakutat
Meters
0.90
0.75
0.60
0.45
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0.15
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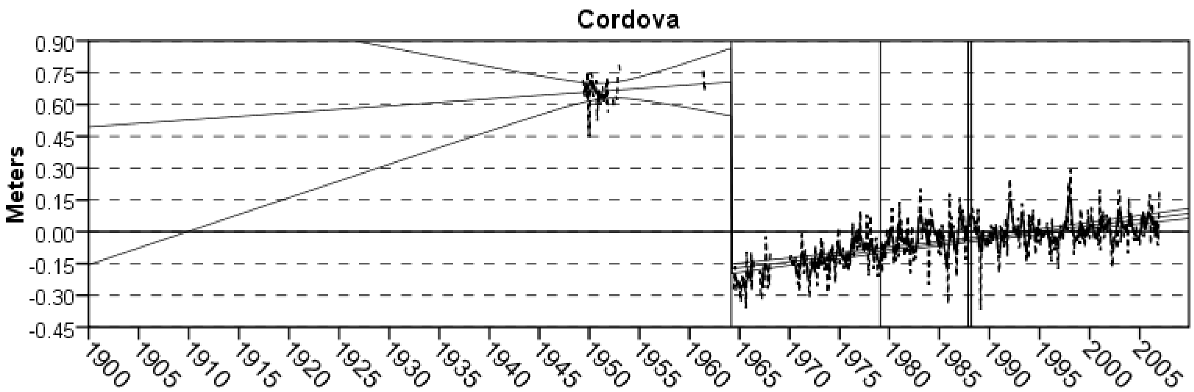
-0.15
-0.30
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005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Meters
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0.75
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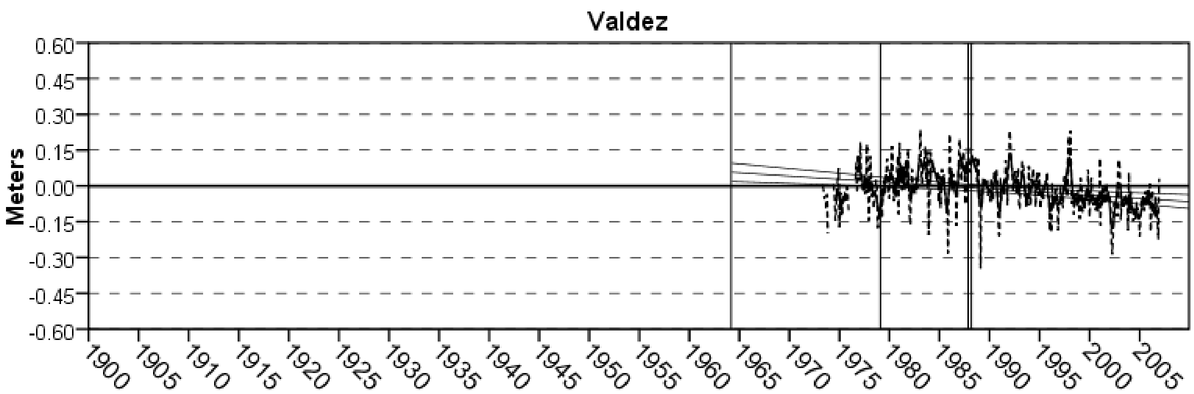
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Valdez
Meters
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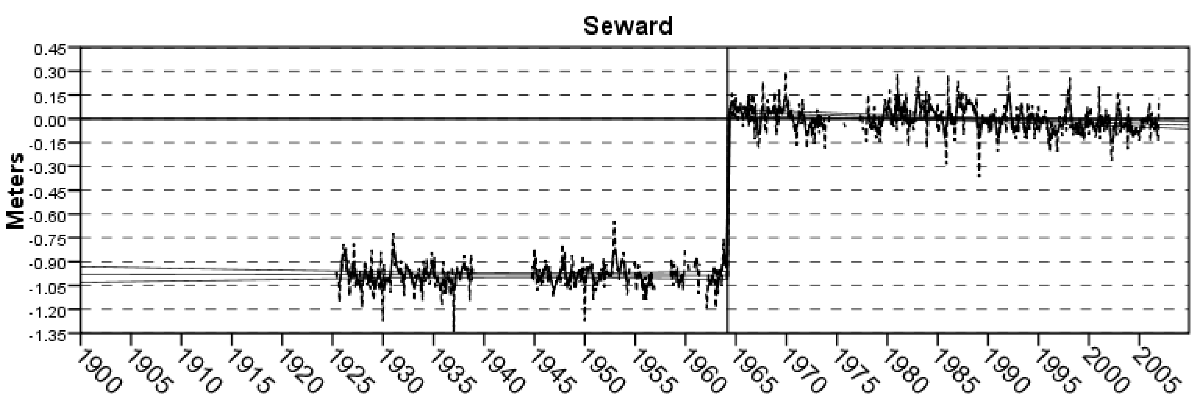
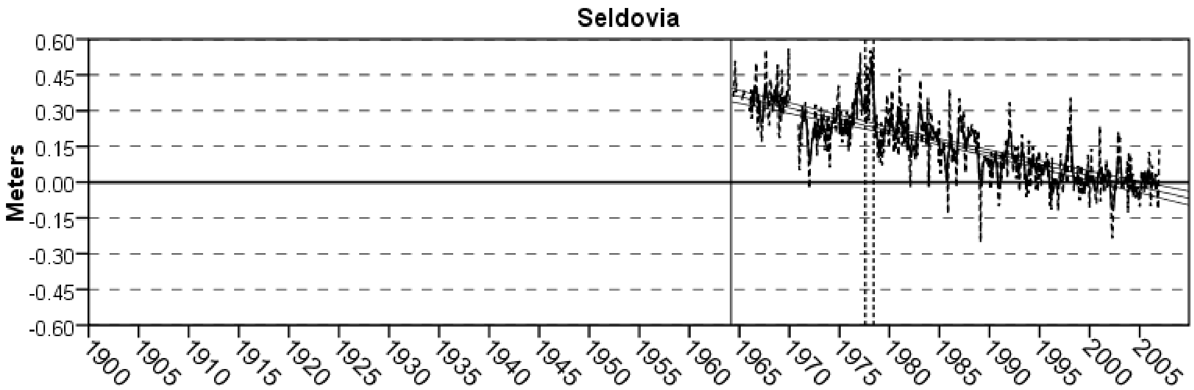
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Seward
Meters
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
-1.35
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


Seldovia
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
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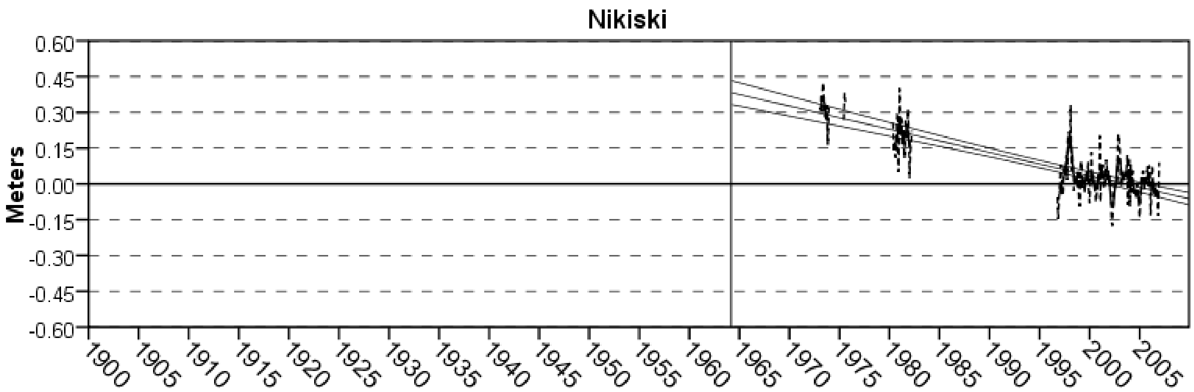
Nikiski
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
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2000
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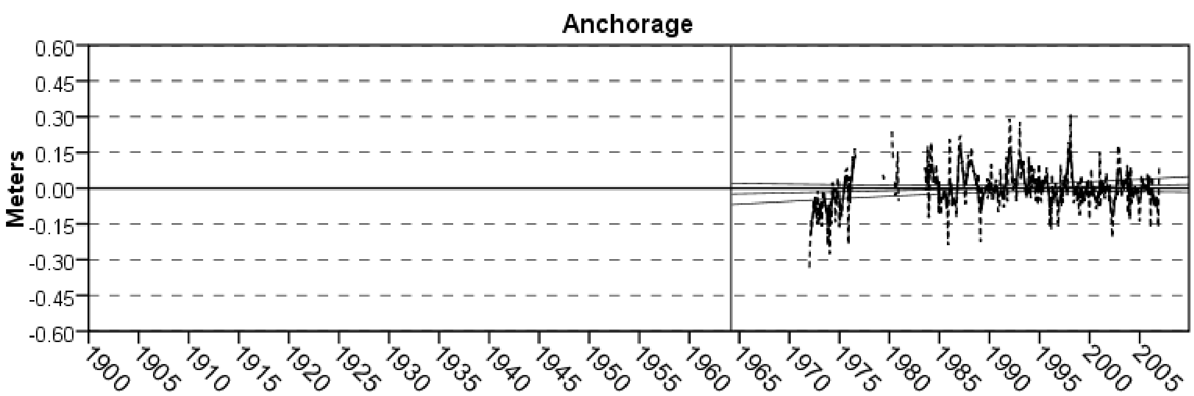
Anchorage
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
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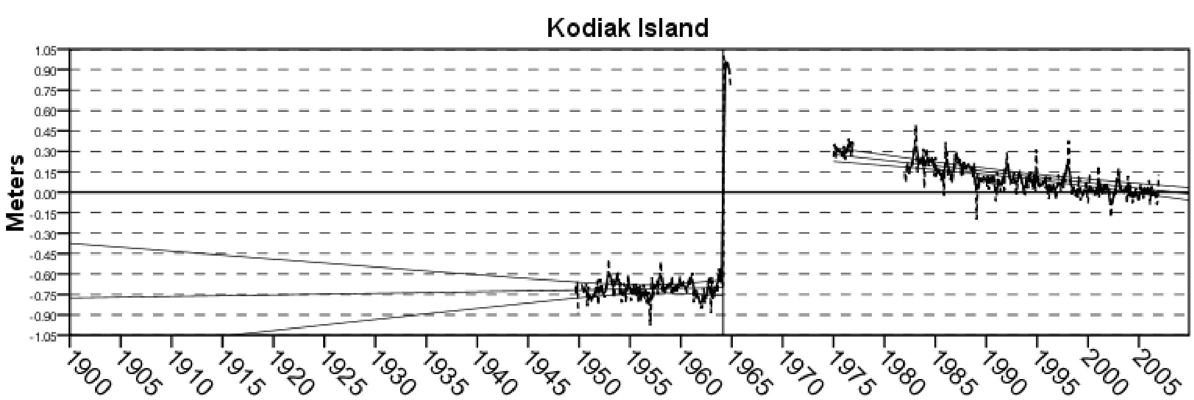
Kodiak Island
Meters
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
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1960
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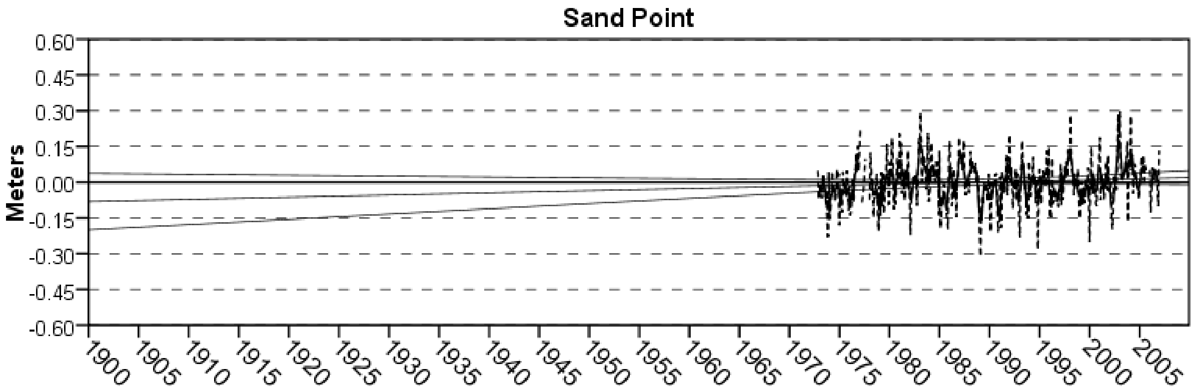
1985
1990
1995
2000
2005


Sand Point
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
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1970
1975
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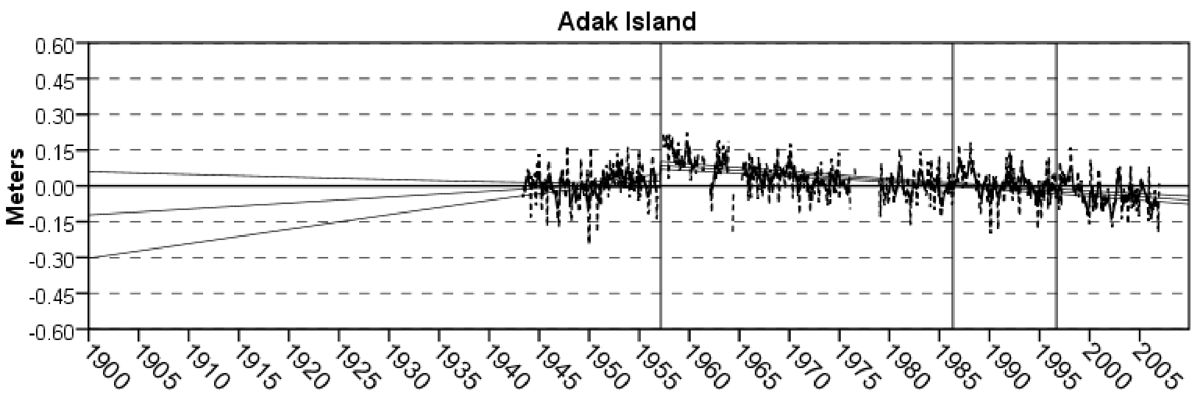
1990
1995
2000
2005


Adak Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
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1960
1965
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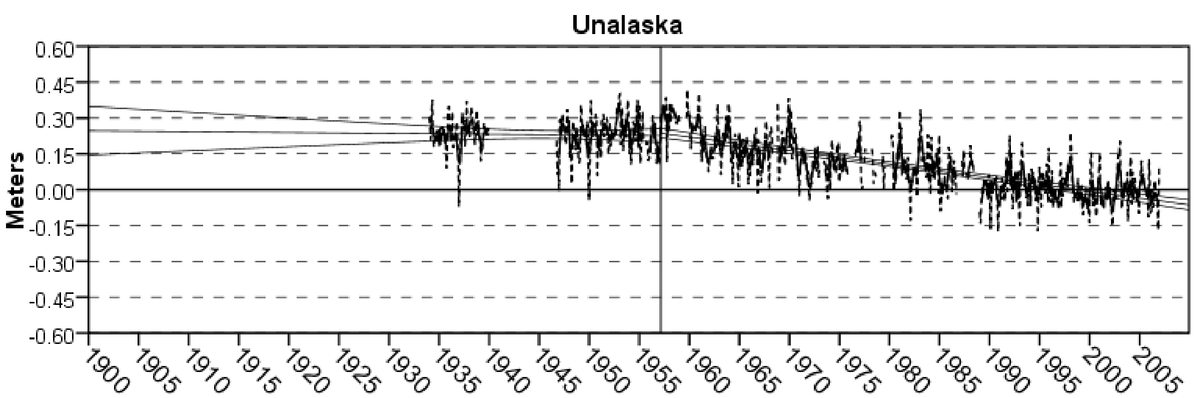
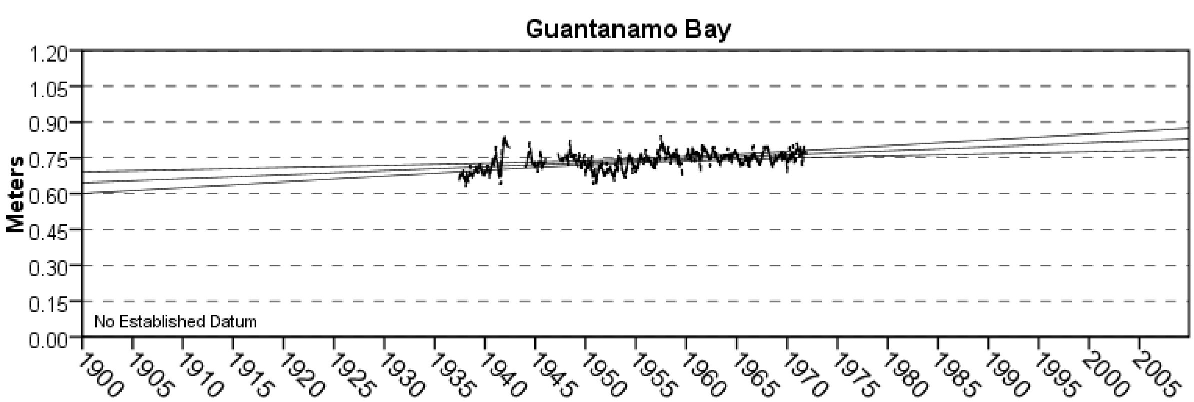
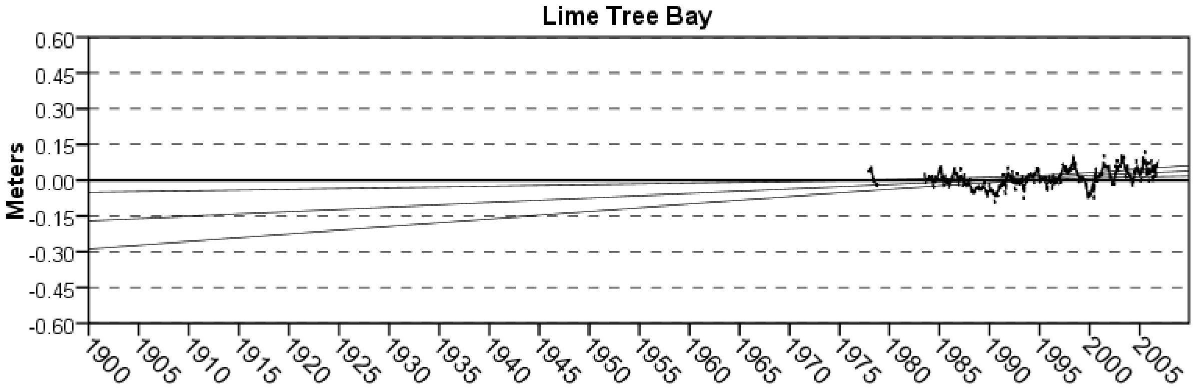
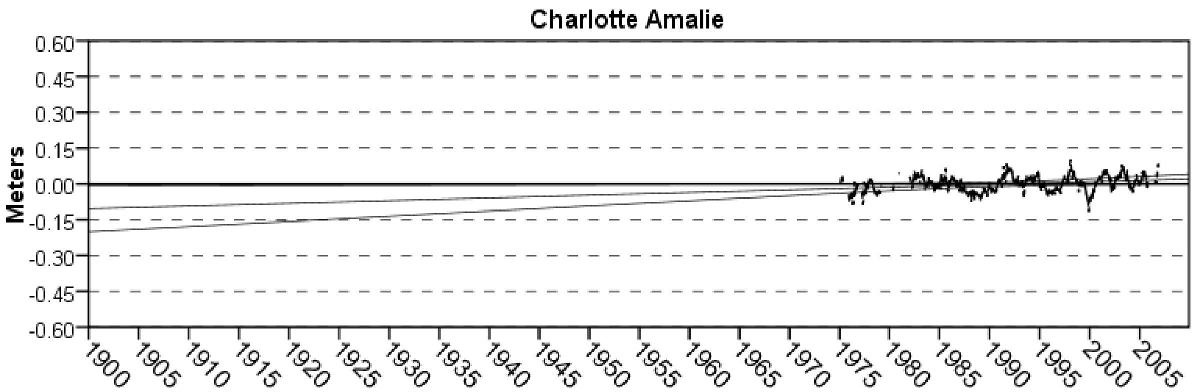
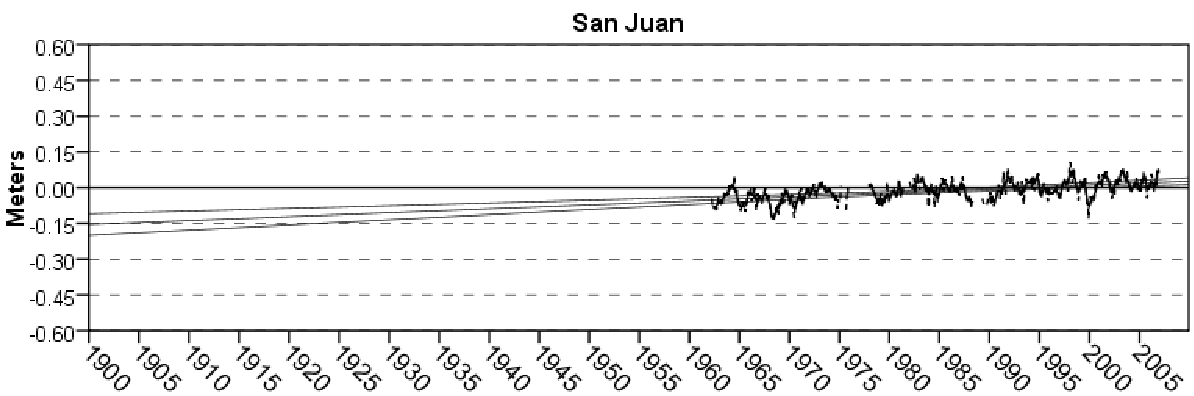
1985
1990
1995
2000
2005

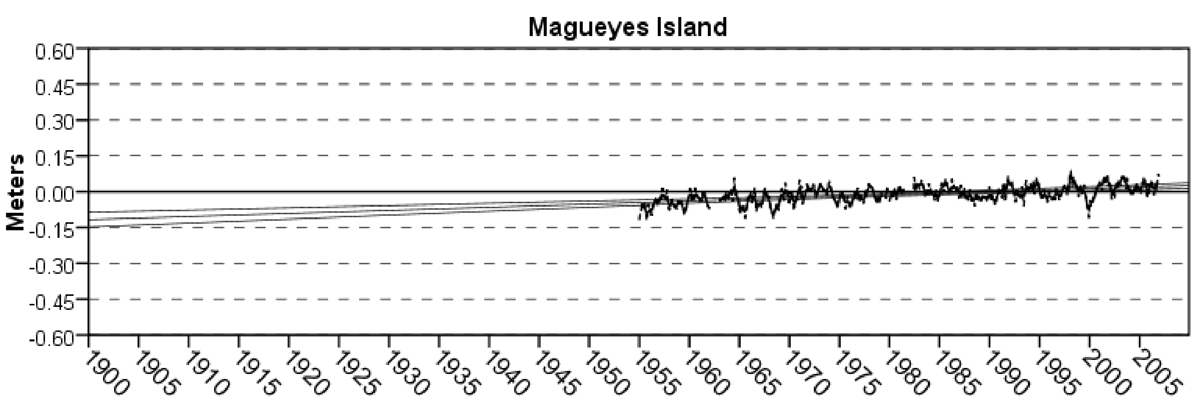

Unalaska
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Guantanamo Bay
Meters
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
No Established Datum
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Lime Tree Bay
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Charlotte Amalie
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


San Juan
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Magueyes Island
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1905
1910
1915
1920
1925
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1935
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2000
2005

Appendix III

Average seasonal cycle
of monthly mean sea level
with 95% confidence intervals

Note: The average of the monthly mean sea levels equals zero.

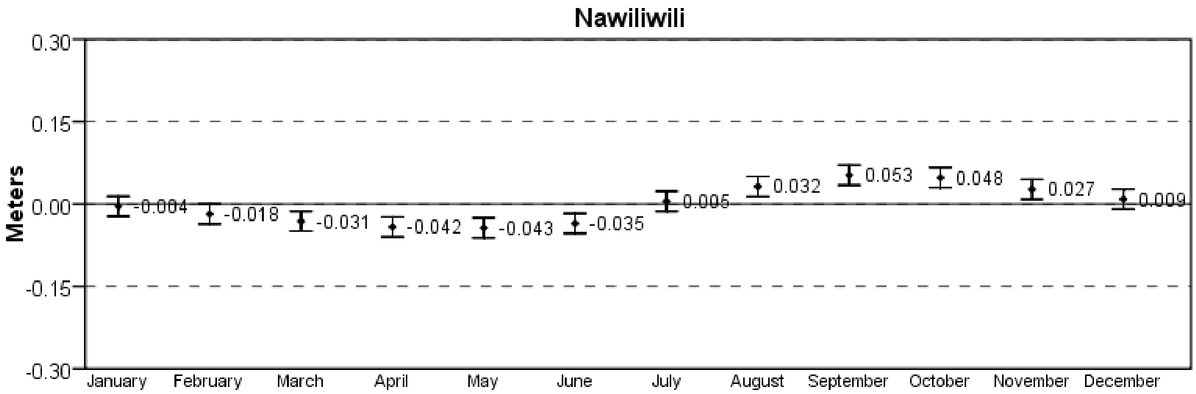
Table B. Average seasonal mean sea level cycle (meters)												
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Adak Island	0.079	0.060	-0.006	-0.065	-0.045	-0.045	-0.056	-0.040	-0.011	0.001	0.041	0.087
Alameda	0.028	0.030	-0.013	-0.061	-0.053	-0.021	0.009	0.021	0.040	0.014	-0.005	0.011
Anchorage	0.038	-0.027	-0.073	-0.093	-0.100	-0.054	0.004	0.039	0.069	0.074	0.056	0.068
Annapolis	-0.124	-0.114	-0.063	-0.001	0.042	0.066	0.062	0.082	0.103	0.061	-0.012	-0.101
Apalachicola	-0.106	-0.084	-0.026	-0.003	0.008	0.022	0.031	0.061	0.112	0.063	0.001	-0.079
Astoria	0.114	0.095	0.038	-0.015	-0.003	0.007	-0.081	-0.121	-0.112	-0.070	0.034	0.113
Atlantic City	-0.077	-0.071	-0.046	-0.018	0.007	0.027	0.023	0.055	0.083	0.067	0.008	-0.059
Baltimore	-0.134	-0.126	-0.073	-0.004	0.048	0.079	0.075	0.092	0.107	0.062	-0.021	-0.106
Bar Harbor	-0.021	-0.024	-0.017	0.000	0.009	0.021	0.012	0.006	0.000	0.008	0.014	-0.009
Beaufort	-0.075	-0.073	-0.054	-0.035	0.001	0.010	-0.009	0.030	0.104	0.114	0.033	-0.046
Bermuda	-0.037	-0.046	-0.049	-0.061	-0.051	-0.022	0.011	0.045	0.070	0.087	0.049	0.003
Boston	-0.041	-0.040	-0.022	0.001	0.015	0.027	0.014	0.014	0.016	0.022	0.016	-0.023
Bridgeport	-0.087	-0.070	-0.045	-0.002	0.025	0.036	0.038	0.049	0.060	0.042	0.003	-0.051
Cambridge	-0.109	-0.091	-0.056	-0.010	0.029	0.049	0.046	0.068	0.095	0.060	0.003	-0.084
Cape May	-0.075	-0.065	-0.045	-0.007	0.012	0.018	0.016	0.042	0.083	0.062	0.008	-0.049
Cedar Key	-0.115	-0.111	-0.066	-0.026	0.021	0.050	0.067	0.086	0.107	0.061	0.001	-0.076
Charleston, OR	0.114	0.097	0.038	-0.057	-0.089	-0.095	-0.082	-0.054	-0.028	-0.012	0.063	0.106
Charleston, SC	-0.091	-0.080	-0.070	-0.046	0.006	0.013	-0.036	0.018	0.131	0.152	0.049	-0.044
Charlotte Amalie	-0.035	-0.050	-0.050	-0.037	-0.035	-0.020	0.013	0.031	0.066	0.079	0.045	-0.007
Cherry Point	0.080	0.063	0.020	-0.055	-0.070	-0.051	-0.033	-0.021	-0.027	-0.023	0.048	0.070
Ches Bay Brdg Tunnel	-0.081	-0.054	-0.037	-0.007	0.013	0.004	-0.007	0.034	0.099	0.082	0.009	-0.055
Chesapeake City	-0.116	-0.098	-0.057	-0.016	0.055	0.073	0.054	0.065	0.103	0.050	-0.021	-0.093
Chuuk	-0.054	-0.007	0.035	0.049	0.034	0.012	-0.002	-0.007	-0.002	0.011	-0.012	-0.056
Clearwater Beach	-0.101	-0.096	-0.068	-0.032	0.013	0.031	0.039	0.059	0.111	0.077	0.031	-0.066
Colonial Beach	-0.122	-0.094	-0.048	-0.001	0.048	0.053	0.046	0.075	0.107	0.052	-0.026	-0.090
Cordova	0.069	0.033	-0.027	-0.085	-0.117	-0.111	-0.098	-0.040	0.031	0.113	0.120	0.112
Crescent City	0.085	0.068	-0.001	-0.080	-0.087	-0.077	-0.037	-0.009	0.014	0.005	0.038	0.081
Dauphin Island	-0.105	-0.098	-0.048	-0.004	0.025	0.022	0.000	0.045	0.126	0.086	0.018	-0.065

Table B. Average seasonal mean sea level cycle (meters)												
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Daytona Bch Shores	-0.067	-0.060	-0.085	-0.066	-0.026	-0.019	-0.074	-0.029	0.130	0.187	0.109	0.000
Eastport	-0.008	-0.014	-0.005	0.001	0.006	0.011	0.004	-0.009	-0.011	0.004	0.018	0.004
Eugene Island	-0.119	-0.094	-0.040	0.031	0.062	0.055	-0.005	0.027	0.118	0.076	-0.019	-0.091
Fernandina Beach	-0.091	-0.087	-0.081	-0.051	-0.004	-0.005	-0.073	-0.017	0.157	0.209	0.081	-0.038
Fort Myers	-0.097	-0.097	-0.060	-0.034	-0.001	0.037	0.049	0.076	0.112	0.069	0.011	-0.065
Fort Pulaski	-0.098	-0.094	-0.080	-0.047	0.012	0.013	-0.048	0.017	0.148	0.172	0.053	-0.049
Freeport	-0.106	-0.095	-0.058	0.005	0.046	0.014	-0.060	-0.013	0.149	0.137	0.045	-0.065
Friday Harbor	0.089	0.070	0.021	-0.049	-0.069	-0.058	-0.047	-0.039	-0.037	-0.021	0.045	0.095
Galveston Pier 21	-0.111	-0.095	-0.054	0.011	0.056	0.030	-0.047	-0.012	0.141	0.126	0.022	-0.068
GalvPleasure Pier	-0.123	-0.101	-0.058	0.008	0.052	0.019	-0.047	0.000	0.153	0.134	0.032	-0.071
Garibaldi	0.147	0.118	0.070	-0.044	-0.104	-0.121	-0.129	-0.108	-0.064	-0.035	0.101	0.169
Gloucester Point	-0.091	-0.074	-0.032	-0.010	0.021	0.021	0.000	0.046	0.100	0.083	0.004	-0.068
Grand Isle	-0.106	-0.091	-0.053	-0.010	0.029	0.026	-0.008	0.036	0.137	0.097	0.013	-0.071
Guam	-0.065	-0.034	-0.004	0.022	0.032	0.053	0.067	0.052	0.022	-0.018	-0.053	-0.073
Guantanamo Bay	-0.047	-0.053	-0.043	-0.039	-0.019	-0.011	0.002	0.035	0.074	0.080	0.037	-0.017
Hilo	-0.005	-0.022	-0.025	-0.035	-0.044	-0.036	-0.003	0.039	0.052	0.045	0.030	0.003
Honolulu	-0.010	-0.019	-0.026	-0.037	-0.035	-0.024	0.003	0.030	0.049	0.043	0.026	0.003
Johnston Atoll	0.016	-0.020	-0.046	-0.055	-0.065	-0.058	-0.002	0.041	0.057	0.062	0.044	0.025
Juneau	0.028	-0.006	-0.045	-0.078	-0.083	-0.038	-0.036	-0.023	0.004	0.085	0.096	0.097
Kahului	-0.005	-0.015	-0.025	-0.039	-0.043	-0.024	0.000	0.031	0.056	0.044	0.024	-0.004
Ketchikan	0.085	0.048	-0.010	-0.058	-0.087	-0.072	-0.085	-0.084	-0.045	0.061	0.119	0.128
Key West	-0.062	-0.077	-0.069	-0.048	-0.020	-0.015	-0.011	0.029	0.091	0.127	0.072	-0.017
Kings Point	-0.083	-0.078	-0.039	-0.002	0.022	0.039	0.038	0.053	0.065	0.047	0.004	-0.066
Kiptopeke	-0.078	-0.065	-0.037	-0.019	0.008	0.013	0.000	0.039	0.096	0.085	0.017	-0.058
Kodiak Island	0.061	0.020	-0.032	-0.054	-0.079	-0.071	-0.066	-0.026	0.023	0.061	0.074	0.088
Kwajalein	-0.057	-0.012	0.026	0.035	0.029	0.016	0.016	0.008	0.006	0.010	-0.023	-0.053
La Jolla	-0.014	-0.037	-0.065	-0.078	-0.053	-0.015	0.036	0.063	0.079	0.050	0.025	0.009
Lewes	-0.080	-0.062	-0.039	-0.011	0.016	0.022	0.013	0.040	0.079	0.067	0.010	-0.057
Lewisetta	-0.109	-0.084	-0.053	-0.007	0.035	0.039	0.036	0.066	0.107	0.061	-0.012	-0.080

Table B. Average seasonal mean sea level cycle (meters)												
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Lime Tree Bay	-0.036	-0.052	-0.060	-0.047	-0.027	-0.013	0.015	0.035	0.068	0.075	0.047	-0.004
Los Angeles	-0.010	-0.028	-0.061	-0.078	-0.053	-0.014	0.034	0.056	0.073	0.049	0.022	0.009
Magueyes Island	-0.038	-0.048	-0.048	-0.046	-0.037	-0.019	0.019	0.041	0.061	0.075	0.048	-0.007
Mayport	-0.078	-0.081	-0.083	-0.065	-0.024	-0.021	-0.075	-0.008	0.151	0.211	0.092	-0.020
Miami Beach	-0.055	-0.067	-0.073	-0.057	-0.019	-0.023	-0.043	-0.005	0.083	0.164	0.100	-0.006
Midway Atoll	0.041	0.023	-0.022	-0.064	-0.056	-0.046	-0.029	0.024	0.050	0.030	0.022	0.028
Mokuoloe	-0.005	-0.017	-0.024	-0.041	-0.044	-0.024	-0.001	0.027	0.049	0.042	0.031	0.005
Montauk	-0.058	-0.055	-0.034	-0.016	0.005	0.021	0.029	0.037	0.048	0.041	0.016	-0.035
Monterey	0.015	0.005	-0.033	-0.073	-0.060	-0.032	0.013	0.035	0.062	0.039	0.017	0.013
Nantucket Island	-0.032	-0.036	-0.038	-0.021	-0.008	0.009	0.016	0.017	0.031	0.037	0.026	0.000
Naples	-0.088	-0.091	-0.064	-0.038	-0.004	0.016	0.023	0.054	0.106	0.095	0.037	-0.046
Nawiliwili	-0.004	-0.018	-0.031	-0.042	-0.043	-0.035	0.005	0.032	0.053	0.048	0.027	0.009
Neah Bay	0.130	0.102	0.048	-0.041	-0.091	-0.106	-0.112	-0.090	-0.065	-0.007	0.090	0.139
New London	-0.067	-0.064	-0.033	-0.005	0.014	0.032	0.032	0.040	0.043	0.039	0.013	-0.045
Newport	-0.056	-0.059	-0.040	-0.022	-0.001	0.028	0.035	0.041	0.047	0.042	0.019	-0.036
Newport Beach	-0.008	-0.027	-0.060	-0.072	-0.053	-0.018	0.033	0.056	0.077	0.047	0.021	0.003
Nikiski	0.072	0.023	-0.052	-0.098	-0.102	-0.087	-0.060	-0.017	0.047	0.080	0.086	0.108
North Spit	0.079	0.063	0.002	-0.075	-0.088	-0.076	-0.031	-0.002	0.025	0.012	0.026	0.064
Ocean City	-0.070	-0.058	-0.048	-0.007	0.004	0.026	0.021	0.046	0.076	0.071	0.003	-0.064
Oregon Inlet Marina	-0.063	-0.066	-0.054	-0.019	0.002	0.021	0.018	0.026	0.097	0.070	0.011	-0.043
Padre Island	-0.063	-0.067	-0.042	-0.010	0.006	-0.027	-0.082	-0.037	0.112	0.144	0.079	-0.012
Pago Pago	-0.013	-0.007	-0.005	0.004	-0.003	0.000	0.009	0.008	0.011	0.004	0.000	-0.006
Panama City	-0.119	-0.108	-0.062	-0.029	0.014	0.030	0.034	0.071	0.131	0.085	0.026	-0.073
Pensacola	-0.114	-0.101	-0.057	-0.016	0.015	0.029	0.023	0.065	0.129	0.090	0.008	-0.071
Philadelphia	-0.111	-0.113	-0.014	0.051	0.059	0.060	0.041	0.052	0.063	0.033	-0.029	-0.092
Point Reyes	0.035	0.029	-0.023	-0.089	-0.079	-0.048	0.007	0.032	0.059	0.033	0.017	0.027
Port Angeles	0.110	0.094	0.042	-0.036	-0.072	-0.086	-0.080	-0.060	-0.052	-0.023	0.068	0.094
Port Chicago	0.028	0.049	0.022	-0.058	-0.036	-0.007	0.036	0.034	0.030	-0.018	-0.051	-0.028
Port Isabel	-0.066	-0.064	-0.036	-0.005	0.014	-0.026	-0.083	-0.032	0.118	0.145	0.064	-0.029

Table B. Average seasonal mean sea level cycle (meters)												
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Port Jefferson	-0.083	-0.061	-0.030	-0.009	0.009	0.034	0.031	0.047	0.058	0.046	0.011	-0.054
Port Mansfield	-0.115	-0.101	-0.047	0.033	0.085	0.029	-0.062	-0.043	0.104	0.132	0.050	-0.065
Port Orford	0.117	0.091	0.034	-0.063	-0.106	-0.113	-0.073	-0.031	-0.004	0.001	0.051	0.096
Port San Luis	0.008	-0.012	-0.053	-0.082	-0.059	-0.020	0.025	0.044	0.067	0.046	0.021	0.016
Port Townsend	0.100	0.086	0.045	-0.035	-0.065	-0.070	-0.063	-0.053	-0.051	-0.034	0.053	0.086
Portland	-0.038	-0.037	-0.024	0.004	0.019	0.030	0.021	0.015	0.010	0.013	0.010	-0.022
Portsmouth	-0.071	-0.057	-0.031	-0.023	0.002	0.009	-0.016	0.026	0.099	0.101	0.026	-0.064
Providence	-0.071	-0.065	-0.040	-0.010	0.012	0.039	0.045	0.044	0.042	0.036	0.010	-0.044
Redwood City	-0.003	0.011	-0.019	-0.061	-0.045	-0.006	0.031	0.045	0.063	0.013	-0.014	-0.015
Reedy Point	-0.130	-0.108	-0.045	0.019	0.051	0.059	0.051	0.076	0.095	0.054	-0.021	-0.102
Rincon Island	-0.008	-0.024	-0.062	-0.073	-0.051	-0.016	0.029	0.051	0.073	0.047	0.025	0.008
Rockport	-0.111	-0.101	-0.049	0.019	0.070	0.026	-0.053	-0.029	0.124	0.138	0.034	-0.068
Sabine Pass	-0.109	-0.091	-0.039	0.019	0.056	0.036	-0.037	-0.007	0.132	0.105	0.011	-0.077
San Diego	-0.013	-0.035	-0.062	-0.077	-0.054	-0.013	0.037	0.057	0.077	0.051	0.023	0.009
San Francisco	0.024	0.021	-0.019	-0.061	-0.048	-0.022	0.014	0.026	0.039	0.016	-0.002	0.013
San Juan	-0.033	-0.041	-0.042	-0.037	-0.035	-0.023	0.007	0.031	0.061	0.079	0.045	-0.012
Sand Point	0.138	0.074	-0.005	-0.085	-0.109	-0.107	-0.120	-0.095	-0.003	0.063	0.103	0.147
Sandy Hook	-0.087	-0.081	-0.039	0.002	0.024	0.040	0.035	0.051	0.068	0.051	0.004	-0.068
Santa Barbara	0.000	-0.017	-0.047	-0.087	-0.048	-0.017	0.022	0.047	0.067	0.050	0.021	0.009
Santa Monica	-0.012	-0.029	-0.055	-0.076	-0.053	-0.012	0.037	0.058	0.080	0.046	0.015	0.000
Seattle	0.095	0.074	0.025	-0.035	-0.055	-0.052	-0.052	-0.050	-0.047	-0.028	0.039	0.087
Seavey Island	-0.037	-0.035	-0.004	0.015	0.020	0.030	0.012	0.008	0.001	0.006	0.010	-0.027
Seldovia	0.068	0.038	-0.028	-0.071	-0.103	-0.104	-0.112	-0.051	0.032	0.105	0.109	0.118
Seward	0.059	0.029	-0.038	-0.092	-0.116	-0.106	-0.093	-0.043	0.030	0.126	0.121	0.122
Sewells Point	-0.079	-0.063	-0.036	-0.012	0.010	0.015	-0.008	0.034	0.103	0.090	0.011	-0.066
Sitka	0.094	0.054	0.000	-0.050	-0.091	-0.099	-0.106	-0.084	-0.032	0.068	0.114	0.131
Skagway	-0.024	-0.053	-0.084	-0.099	-0.076	0.001	0.030	0.036	0.053	0.101	0.061	0.053
Solomons Island	-0.111	-0.099	-0.053	-0.007	0.035	0.050	0.043	0.070	0.104	0.066	-0.005	-0.093
South Beach	0.134	0.114	0.051	-0.048	-0.096	-0.109	-0.105	-0.074	-0.044	-0.020	0.069	0.127

Table B. Average seasonal mean sea level cycle (meters)												
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Southport	-0.075	-0.072	-0.061	-0.032	0.001	0.014	-0.004	0.014	0.094	0.115	0.049	-0.044
Springmaid Pier	-0.102	-0.098	-0.075	-0.053	0.005	0.015	-0.016	0.034	0.134	0.145	0.055	-0.044
St. Petersburg	-0.095	-0.097	-0.064	-0.038	0.005	0.036	0.043	0.068	0.107	0.073	0.019	-0.058
The Battery	-0.088	-0.089	-0.049	0.007	0.031	0.044	0.040	0.057	0.064	0.047	-0.003	-0.063
Toke Point	0.171	0.140	0.074	-0.037	-0.096	-0.128	-0.156	-0.135	-0.085	-0.021	0.113	0.159
Unalaska	0.084	0.067	-0.017	-0.064	-0.047	-0.050	-0.070	-0.061	-0.011	0.017	0.054	0.099
Vaca Key	-0.052	-0.070	-0.060	-0.056	-0.028	-0.023	-0.019	0.020	0.088	0.124	0.085	-0.008
Valdez	0.064	0.015	-0.044	-0.095	-0.112	-0.079	-0.067	-0.025	0.043	0.109	0.095	0.096
Wake Island	-0.028	-0.026	-0.022	-0.026	-0.043	-0.018	0.025	0.044	0.048	0.037	0.015	-0.007
Washington	-0.111	-0.091	-0.023	0.024	0.056	0.058	0.037	0.061	0.087	0.044	-0.031	-0.112
Wilmington	-0.065	-0.038	-0.008	-0.008	0.000	0.008	-0.006	0.019	0.081	0.075	0.004	-0.061
Woods Hole	-0.049	-0.056	-0.043	-0.022	-0.002	0.026	0.032	0.036	0.042	0.043	0.023	-0.030
Yakutat	0.078	0.035	-0.018	-0.069	-0.109	-0.104	-0.102	-0.066	0.000	0.105	0.120	0.128


Nawiliwili
Meters
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0.15
0.00
-0.15
-0.30
-0.004
-0.018
-0.031
-0.042
-0.043
-0.035
0.005
0.032
0.053
0.048
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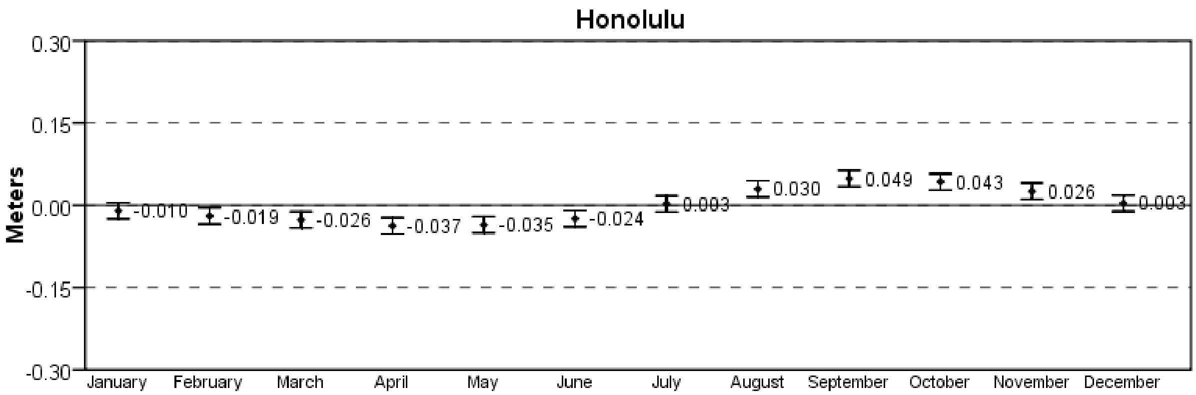
Honolulu
Meters
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0.15
0.00
-0.15
-0.30
-0.010
-0.019
-0.026
-0.037
-0.035
-0.024
0.003
0.030
0.049
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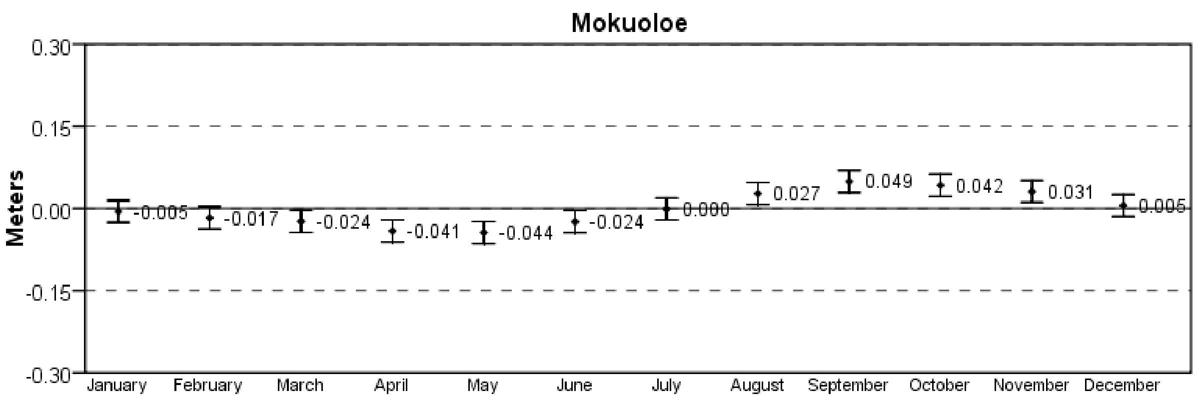
Mokuoloe
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-0.041
-0.044
-0.024
0.000
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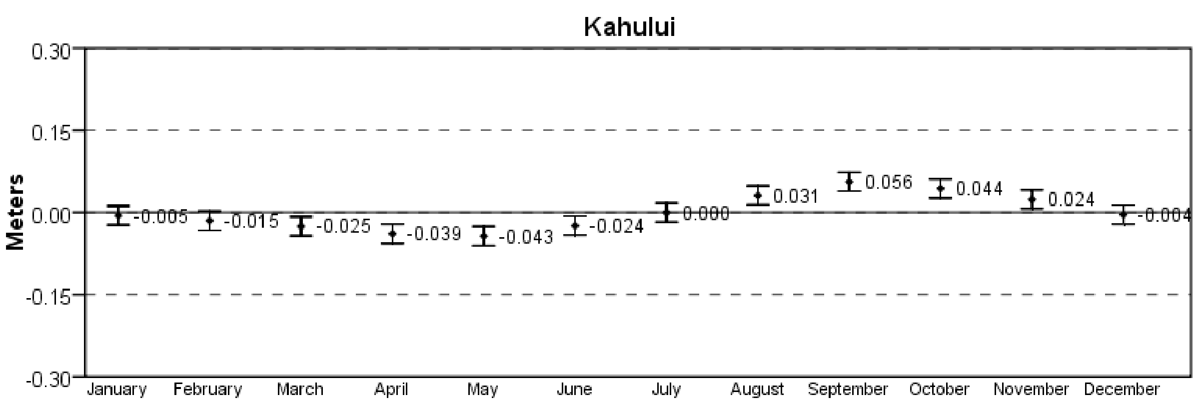
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-0.025
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-0.043
-0.024
0.000
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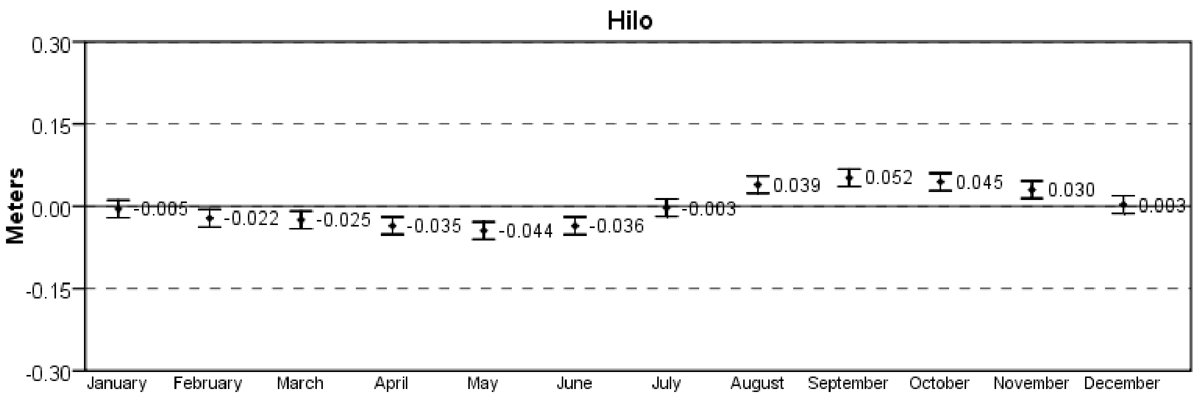
Hilo
Meters
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-0.005
-0.022
-0.025
-0.035
-0.044
-0.036
-0.003
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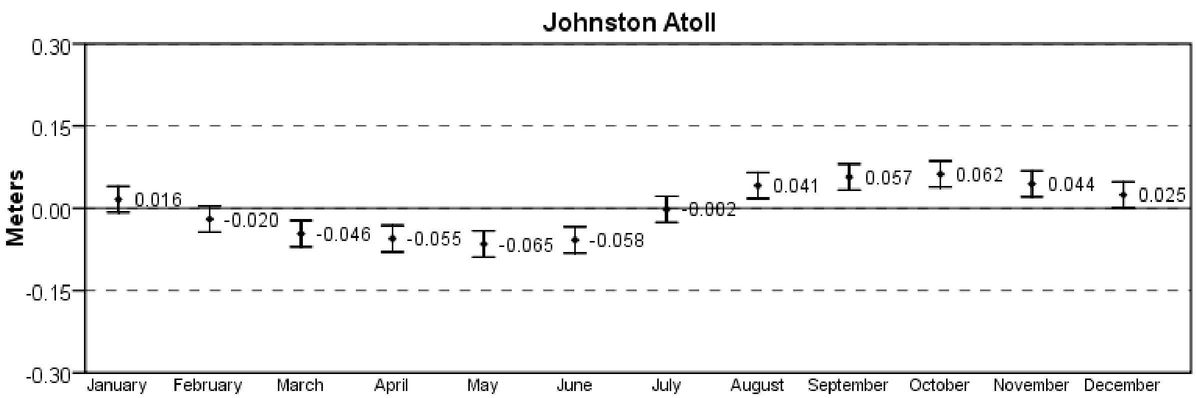
Johnston Atoll
Meters
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-0.020
-0.046
-0.055
-0.065
-0.058
-0.002
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0.057
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0.044
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January
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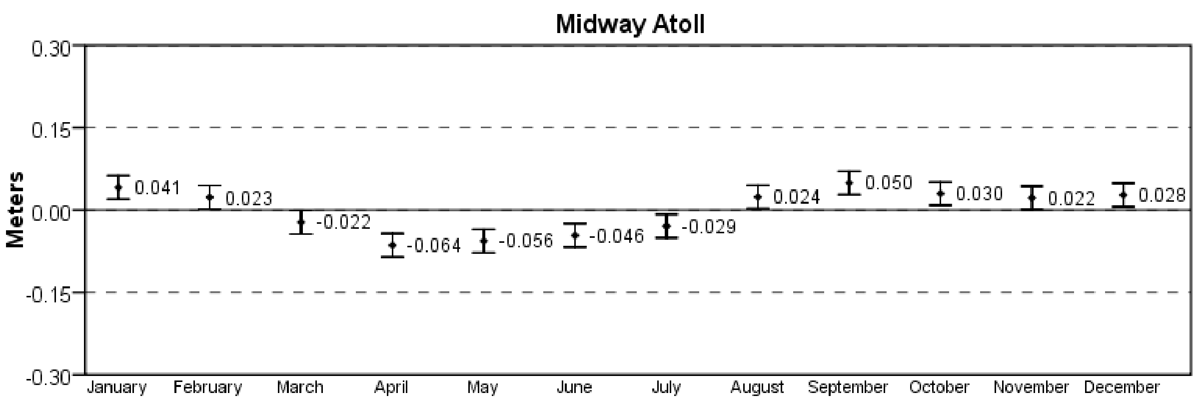
Midway Atoll
Meters
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-0.022
-0.064
-0.056
-0.046
-0.029
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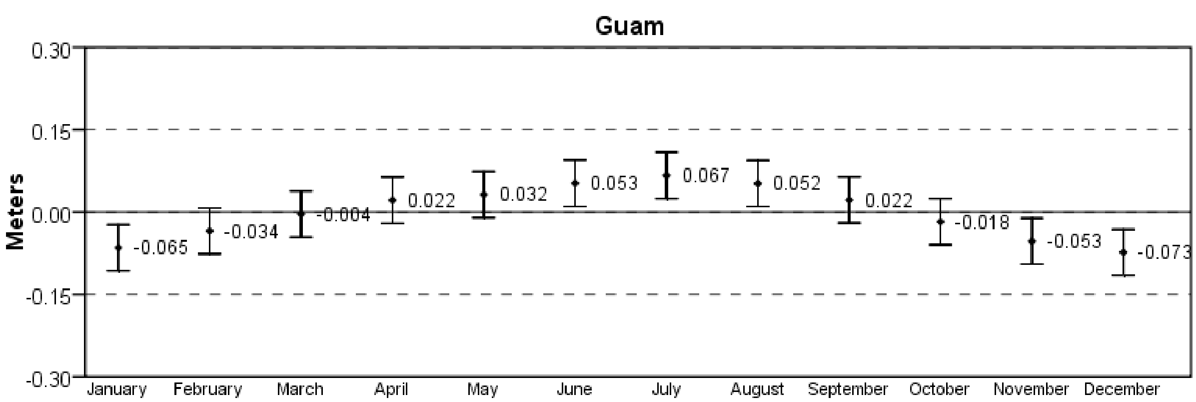
Guam
Meters
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-0.065
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-0.004
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0.032
0.053
0.067
0.052
0.022
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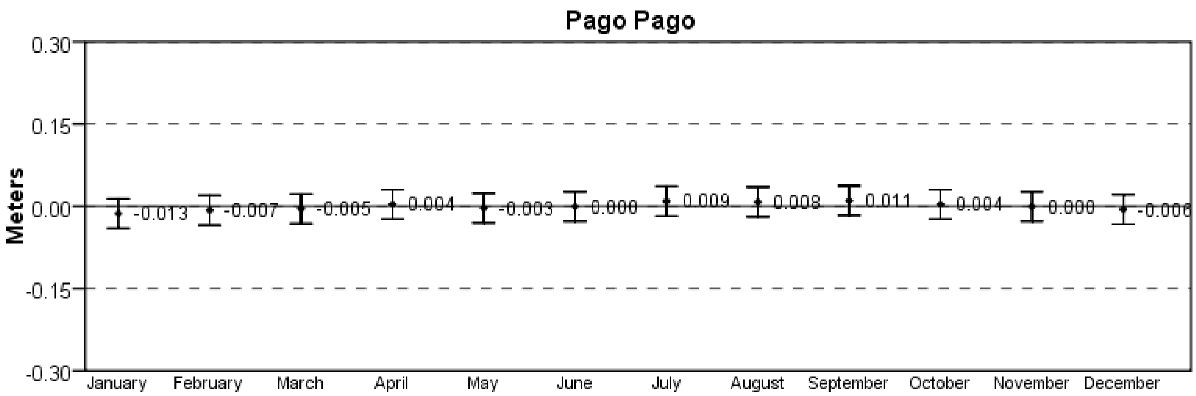
Pago Pago
Meters
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-0.007
-0.005
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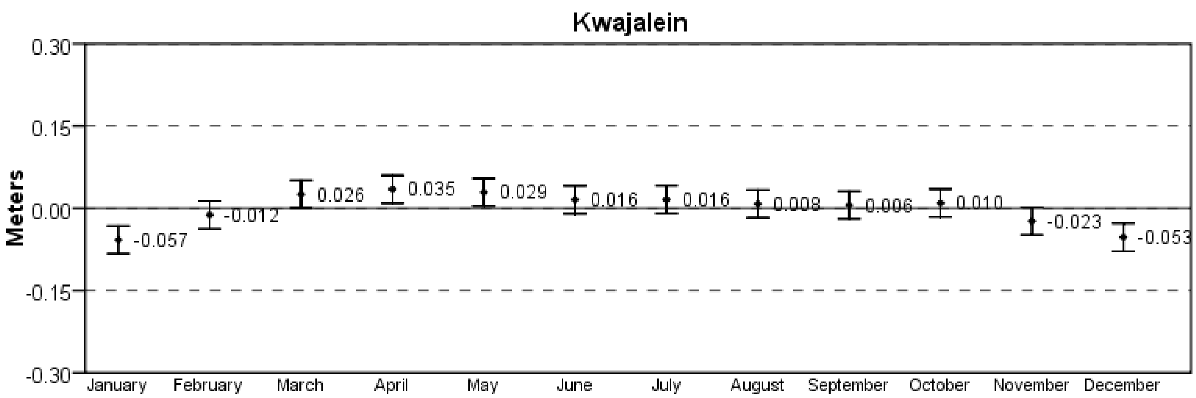
0.000
0.009
0.008
0.011
0.004
0.000
-0.006
January February March April May June July August September October November December


Kwajalein
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0.026
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0.029
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0.016
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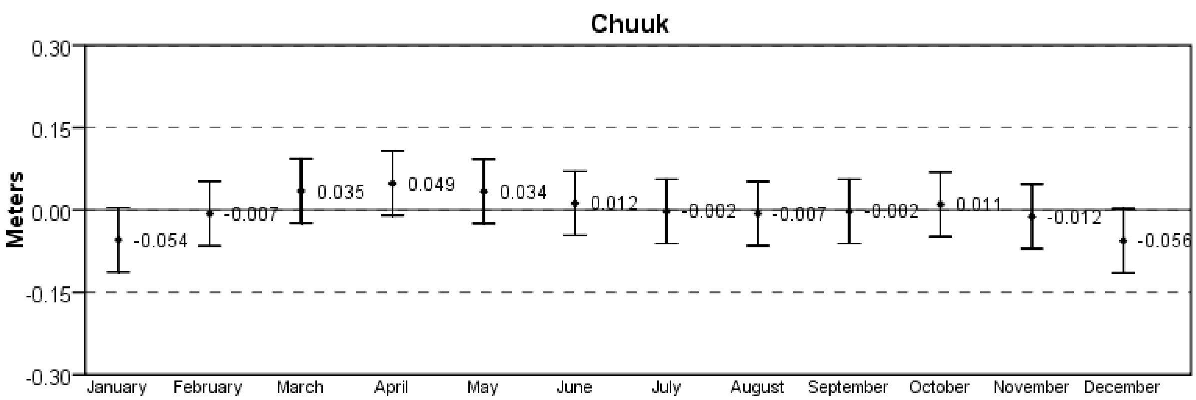
0.010
-0.023
-0.053
January February March April May June July August September October November December


Chuuk
Meters
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0.035
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0.012
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-0.012
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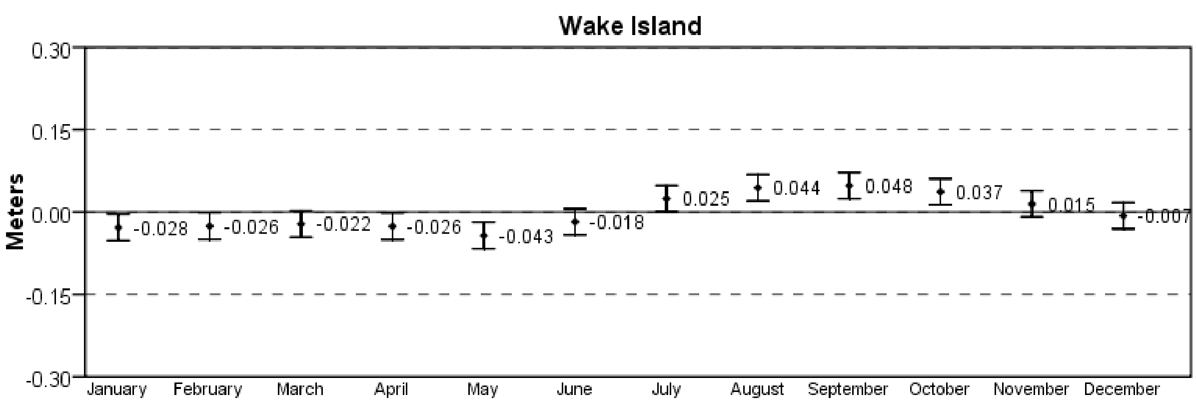
January February March April May June July August September October November December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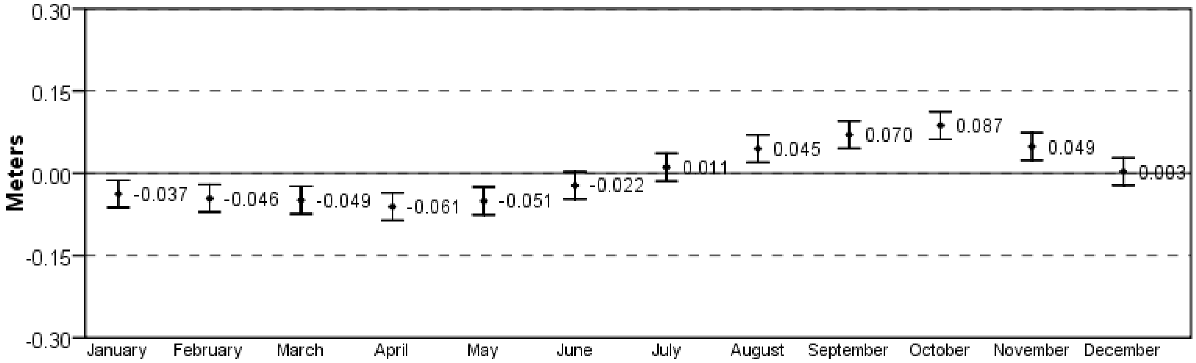
-0.028
-0.026
-0.022
-0.026
-0.043
-0.018
0.025
0.044
0.048
0.037
0.015
-0.007
January February March April May June July August September October November December

Bermuda



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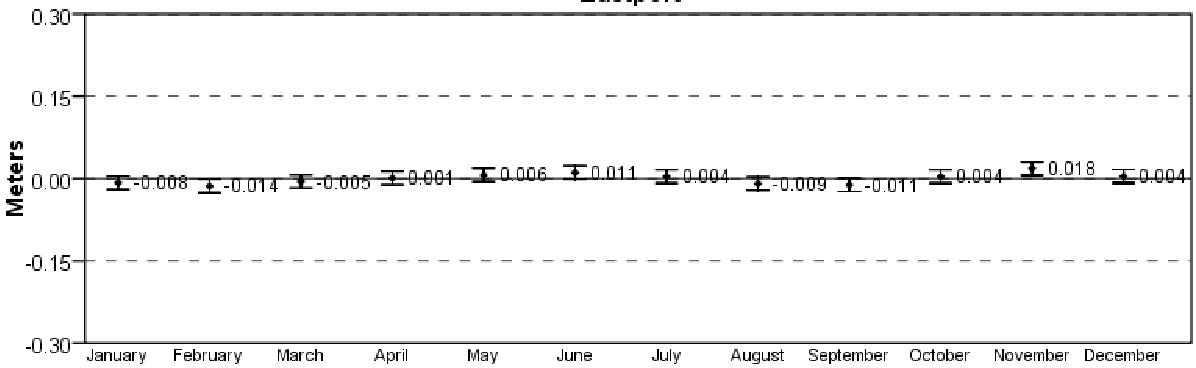

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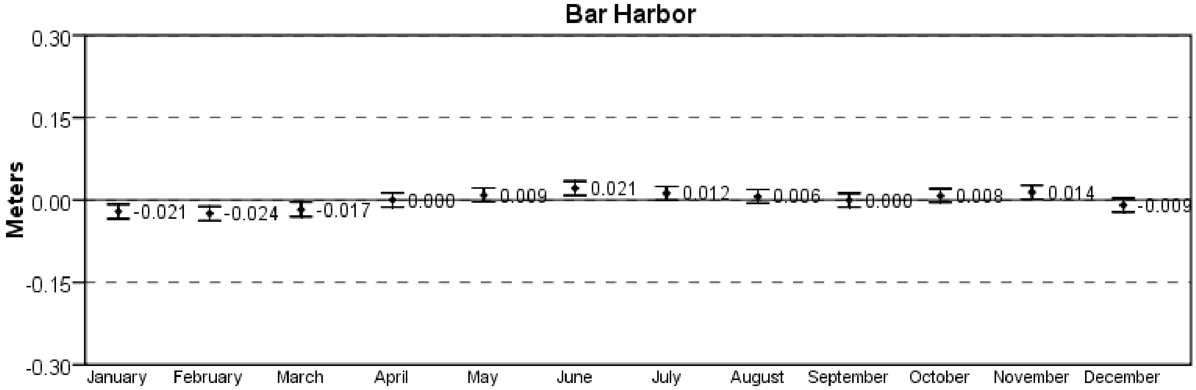
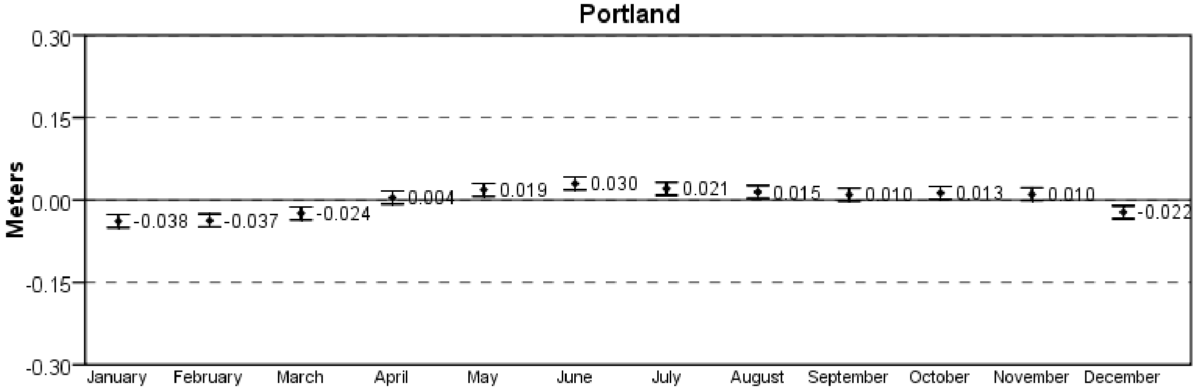
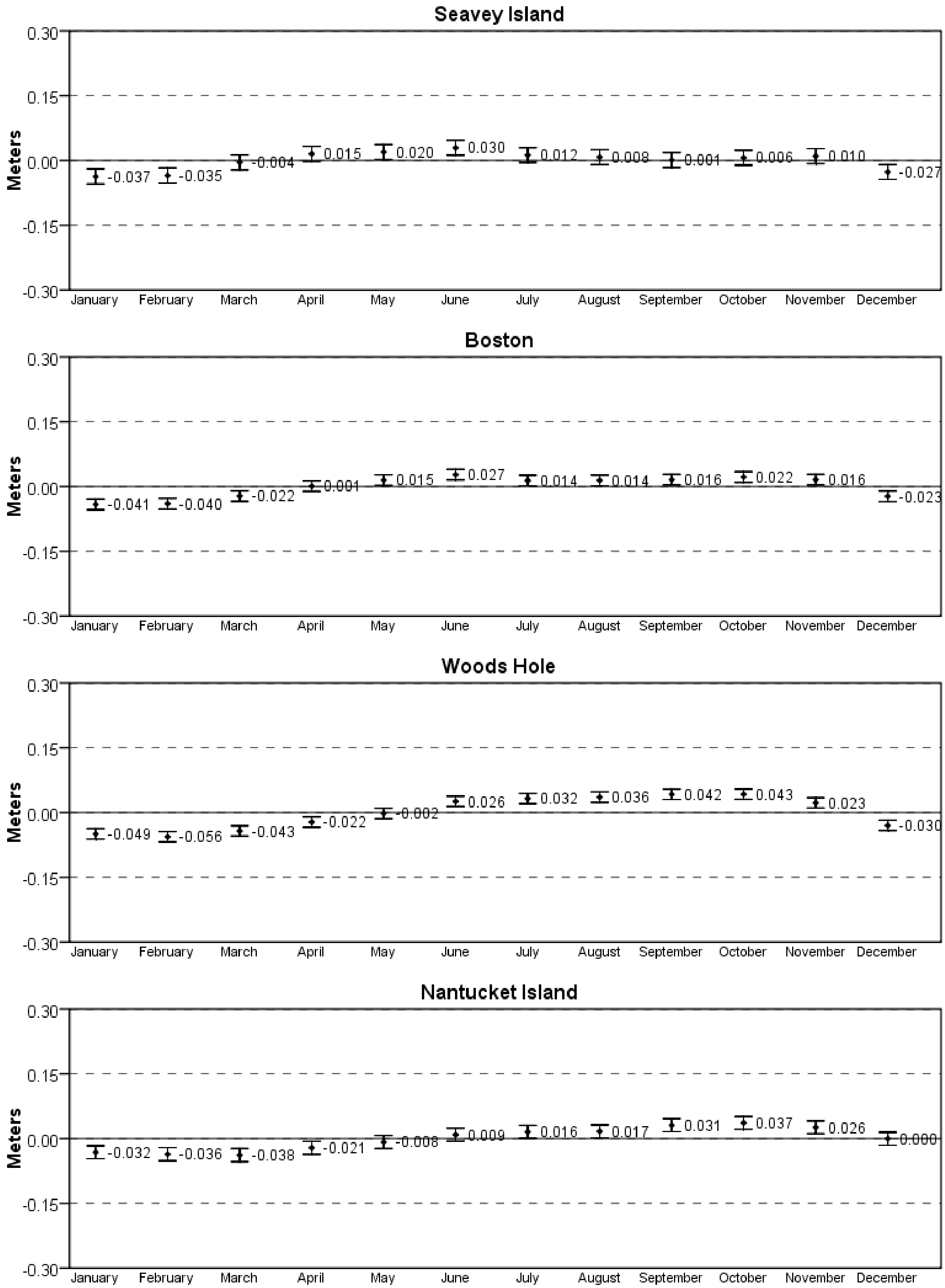


Portland





Seavey Island
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-0.035
-0.004
0.015
0.020
0.030
0.012
0.008
0.001
0.006
0.010
-0.027
Boston
-0.041
-0.040
-0.022
0.001
0.015
0.027
0.014
0.014
0.016
0.022
0.016
-0.023
Woods Hole
-0.049
-0.056
-0.043
-0.022
-0.002
0.026
0.032
0.036
0.042
0.043
0.023
-0.030
Nantucket Island
-0.032
-0.036
-0.038
-0.021
-0.008
0.009
0.016
0.017
0.031
0.037
0.026
0.000
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
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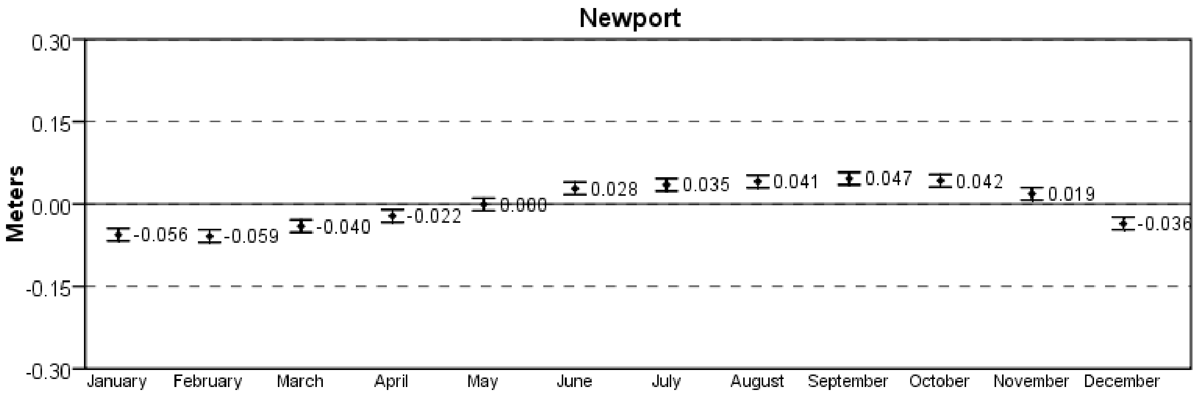
December


Newport
Meters
0.30
0.15
0.00
-0.15
-0.30
January February March April May June July August September October November December
-0.056
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0.035
0.041
0.047
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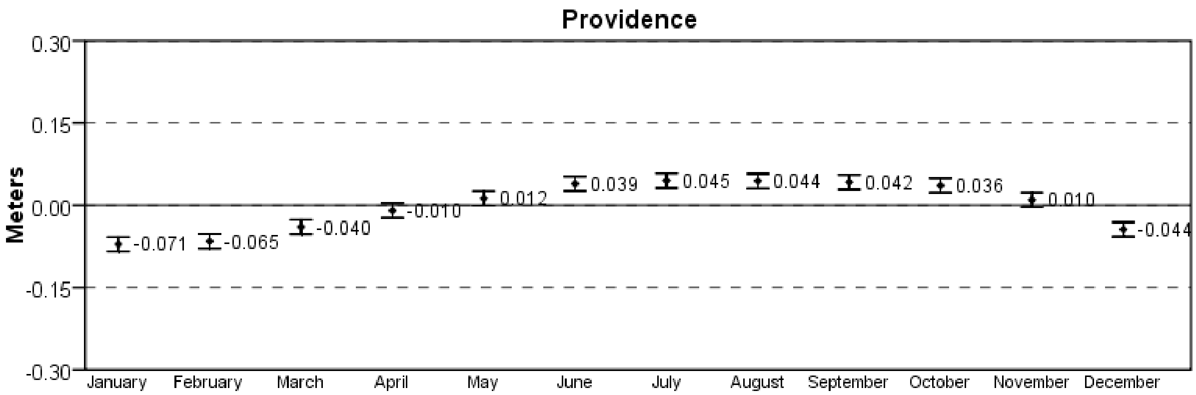
-0.036


Providence
Meters
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0.00
-0.15
-0.30
January February March April May June July August September October November December
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-0.010
0.012
0.039
0.045
0.044
0.042
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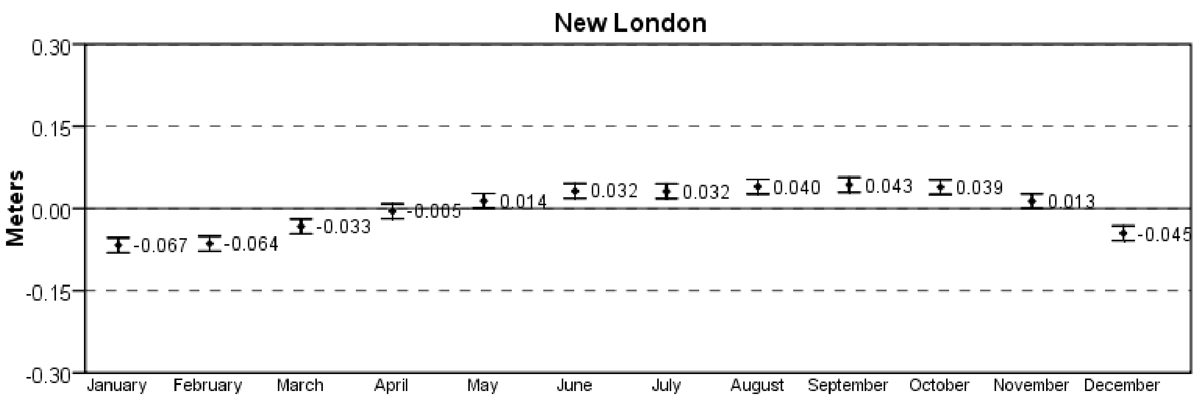
New London
Meters
0.30
0.15
0.00
-0.15
-0.30
January February March April May June July August September October November December
-0.067
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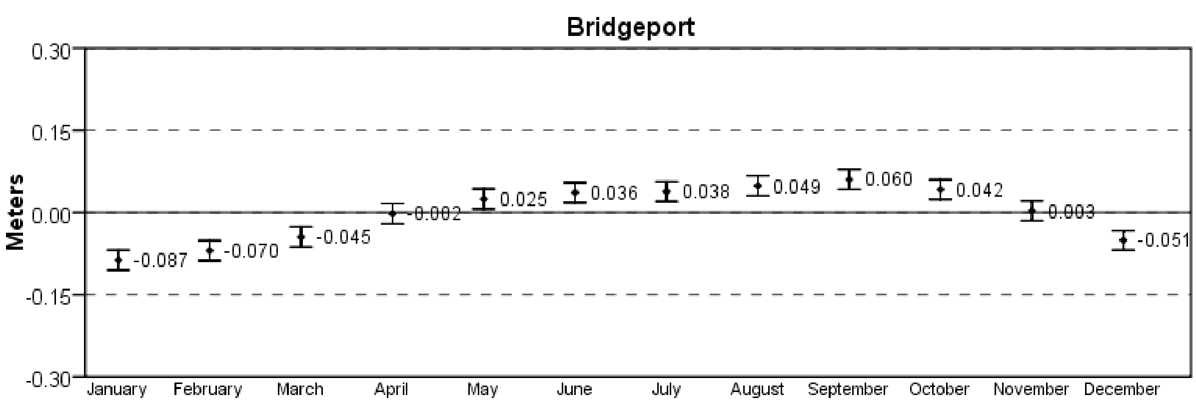
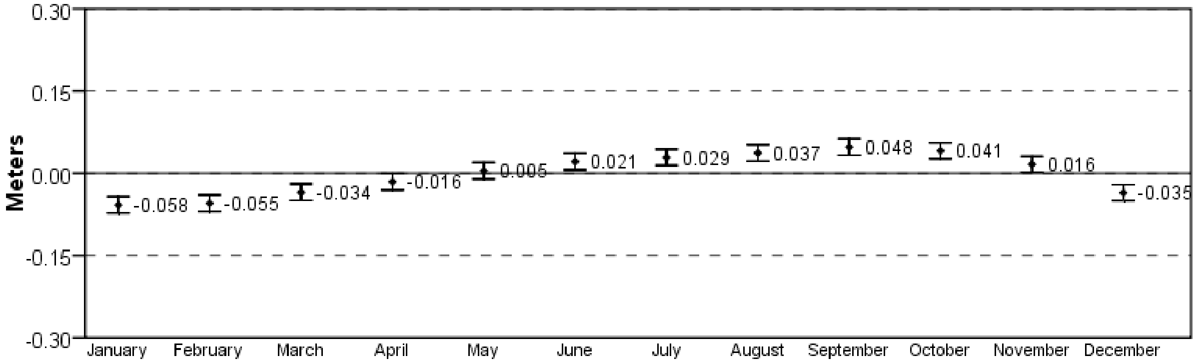
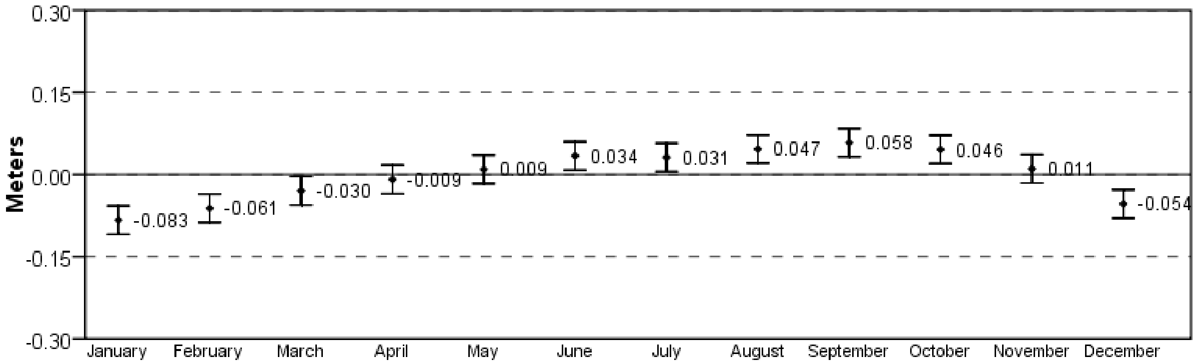
0.032
0.032
0.040
0.043
0.039
0.013
-0.045


Bridgeport
Meters
0.30
0.15
0.00
-0.15
-0.30
January February March April May June July August September October November December
-0.087
-0.070
-0.045
-0.002
0.025
0.036
0.038
0.049
0.060
0.042
0.003
-0.051

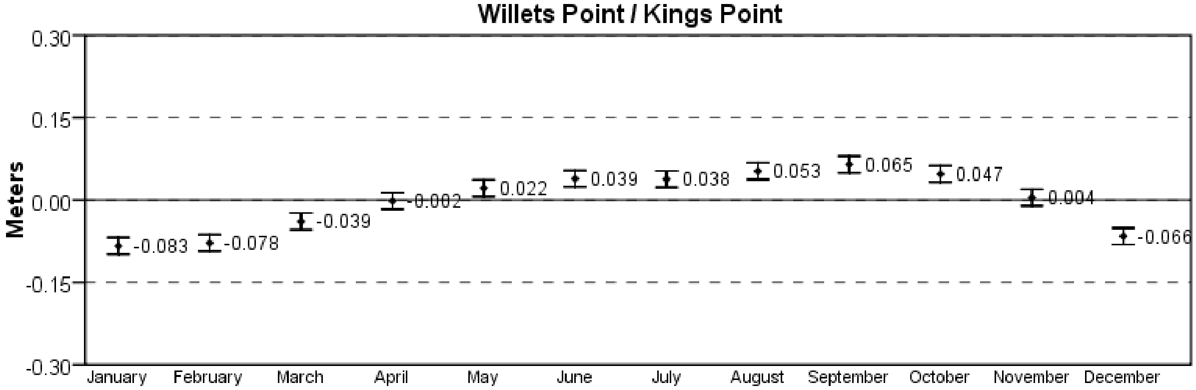
Montauk



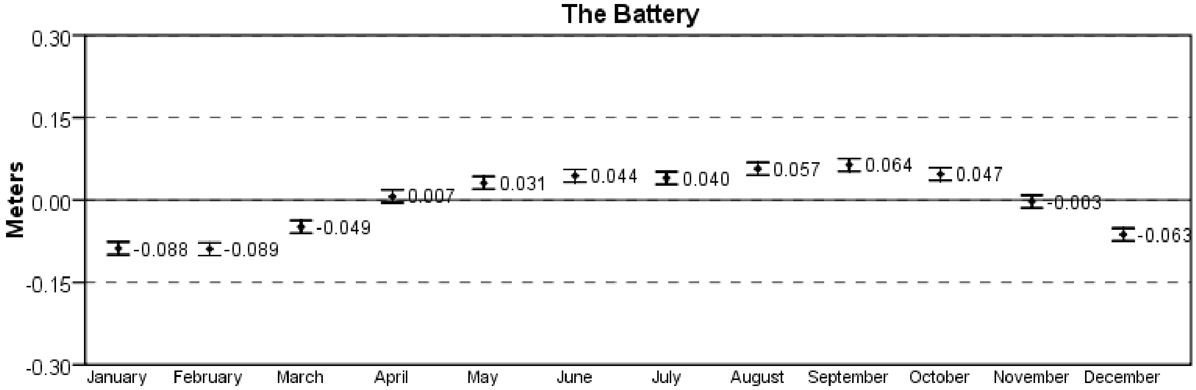
Port Jefferson

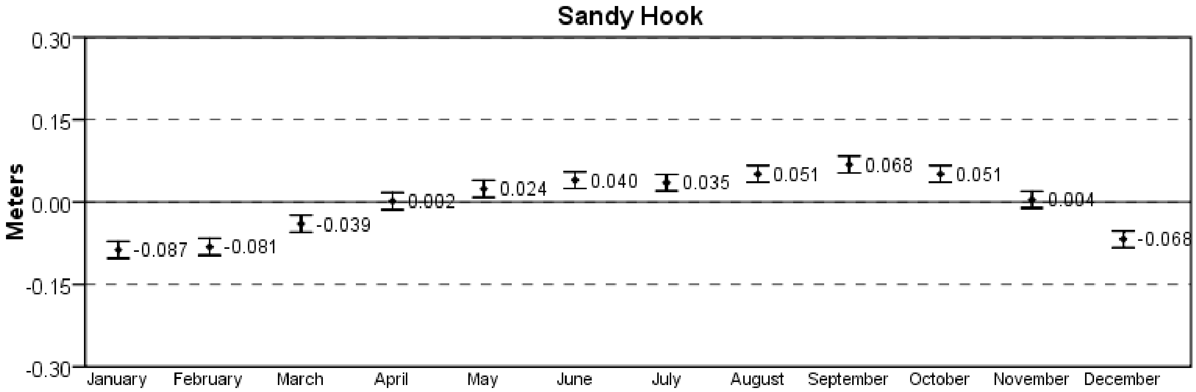


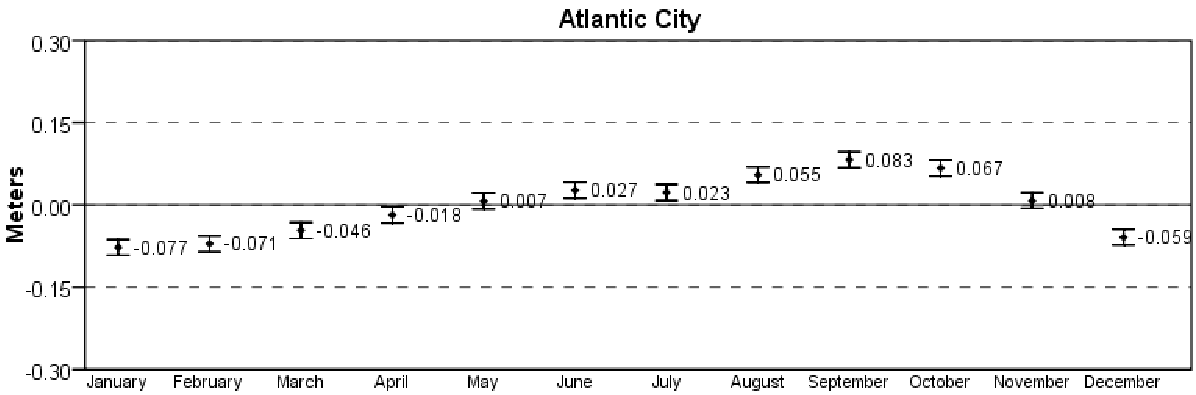
Willets Point / Kings Point



The Battery




Sandy Hook
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.087
-0.081
-0.039
0.002
0.024
0.040
0.035
0.051
0.068
0.051
0.004
-0.068
January
February
March
April
May
June
July
August
September
October
November
December


Atlantic City
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.077
-0.071
-0.046
-0.018
0.007
0.027
0.023
0.055
0.083
0.067
0.008
-0.059
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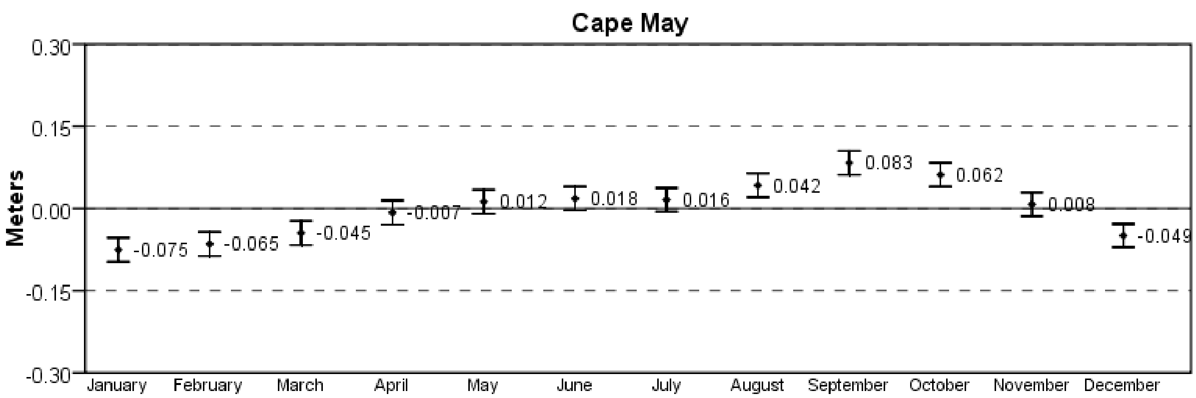
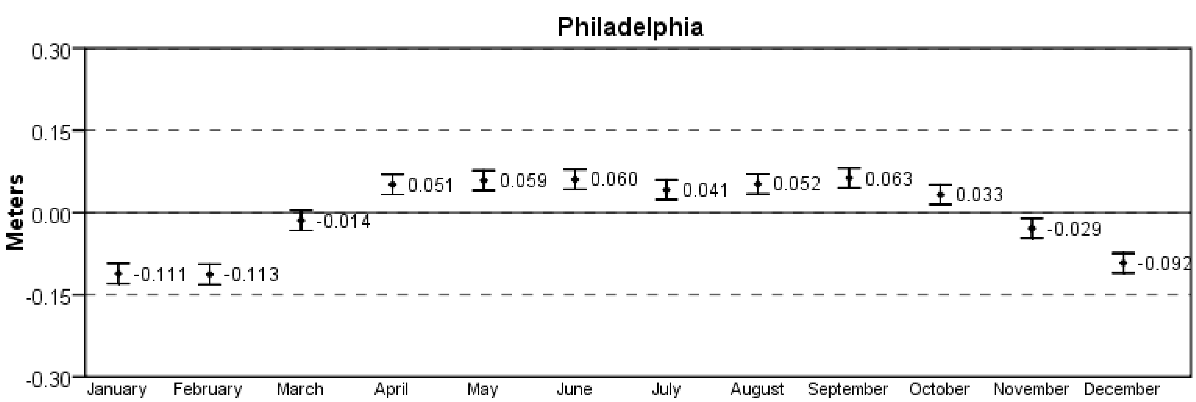
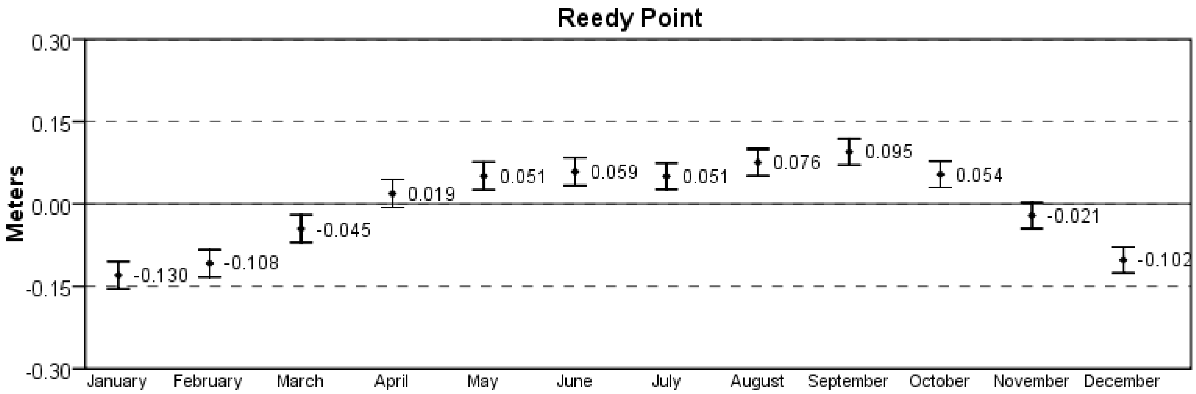
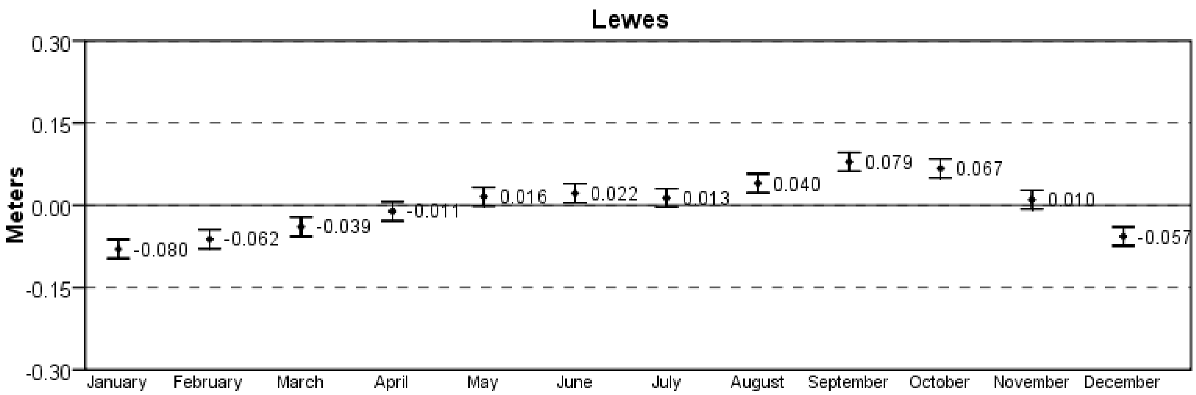
August
September
October
November
December


Cape May
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.075
-0.065
-0.045
-0.007
0.012
0.018
0.016
0.042
0.083
0.062
0.008
-0.049
January
February
March
April
May
June
July
August
September
October
November
December


Philadelphia
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.111
-0.113
-0.014
0.051
0.059
0.060
0.041
0.052
0.063
0.033
-0.029
-0.092
January
February
March
April
May
June
July
August
September
October
November
December


Reedy Point
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.130
-0.108
-0.045
0.019
0.051
0.059
0.051
0.076
0.095
0.054
-0.021
-0.102
January
February
March
April
May
June
July
August
September
October
November
December


Lewes
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.080
-0.062
-0.039
-0.011
0.016
0.022
0.013
0.040
0.079
0.067
0.010
-0.057
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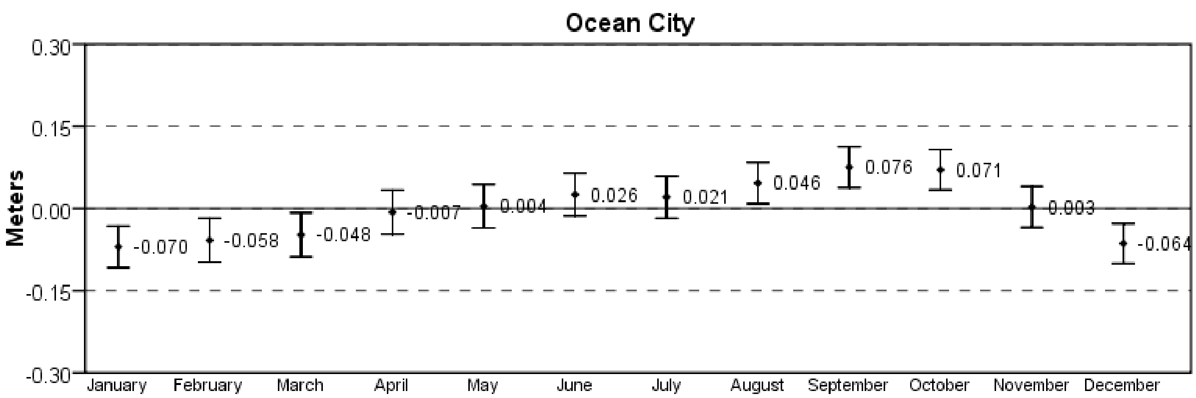
August
September
October
November
December


Ocean City
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.070
-0.058
-0.048
-0.007
0.004
0.026
0.021
0.046
0.076
0.071
0.003
-0.064
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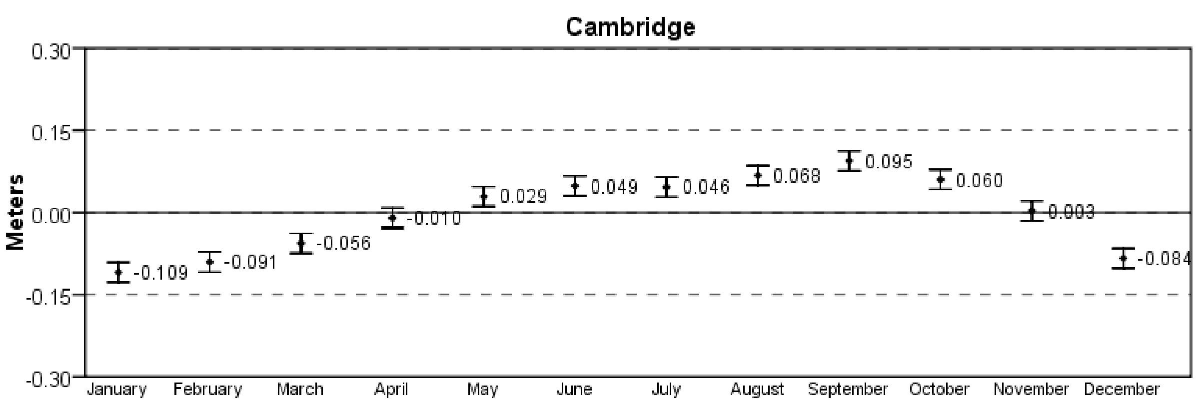
October
November
December


Cambridge
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.109
-0.091
-0.056
-0.010
0.029
0.049
0.046
0.068
0.095
0.060
0.003
-0.084
January
February
March
April
May
June
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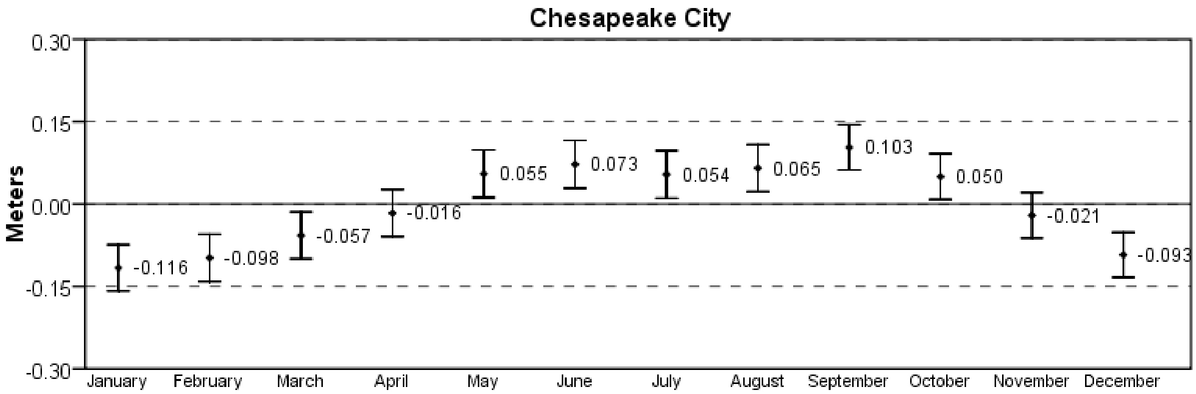
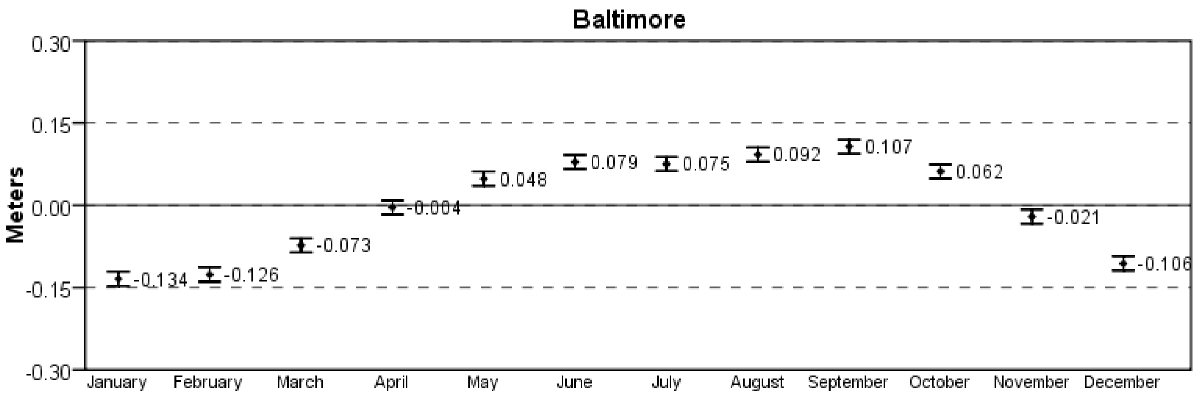
September
October
November
December


Chesapeake City
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.116
-0.098
-0.057
-0.016
0.055
0.073
0.054
0.065
0.103
0.050
-0.021
-0.093
January
February
March
April
May
June
July
August
September
October
November
December


Baltimore
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.134
-0.126
-0.073
-0.004
0.048
0.079
0.075
0.092
0.107
0.062
-0.021
-0.106
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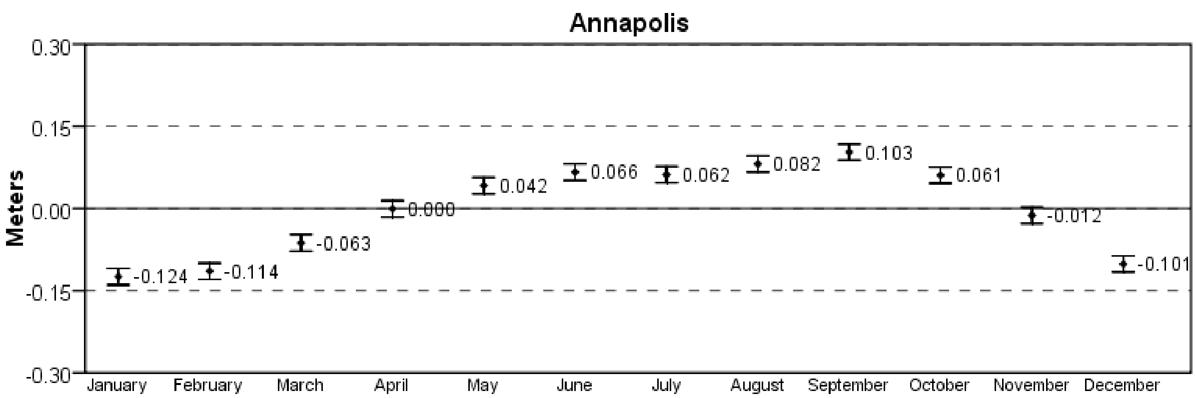
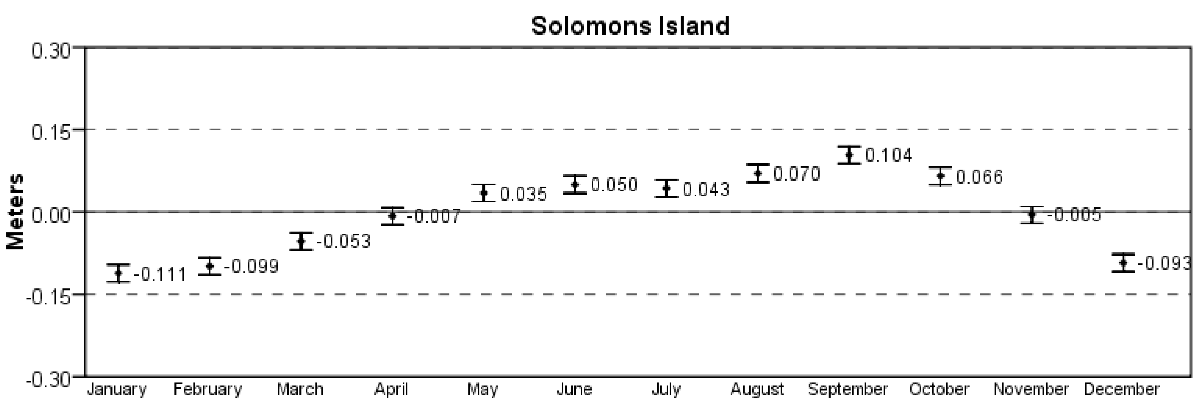
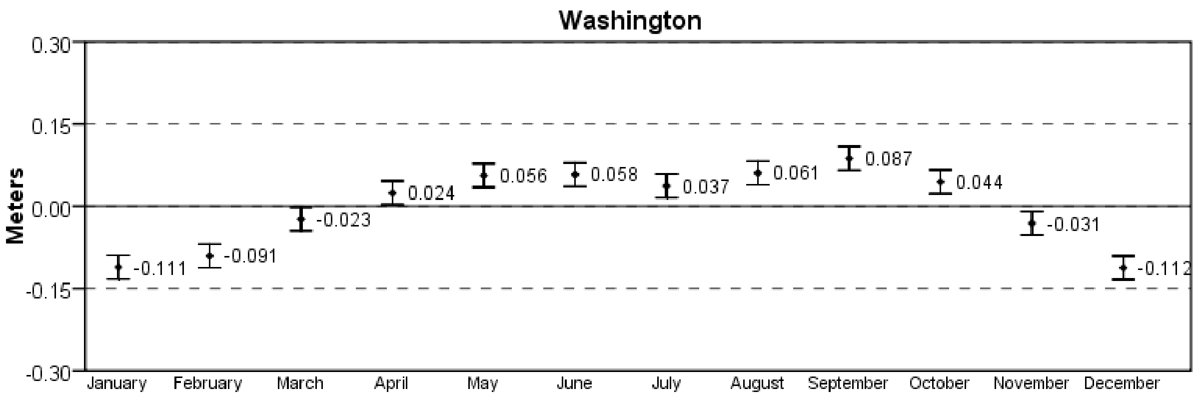
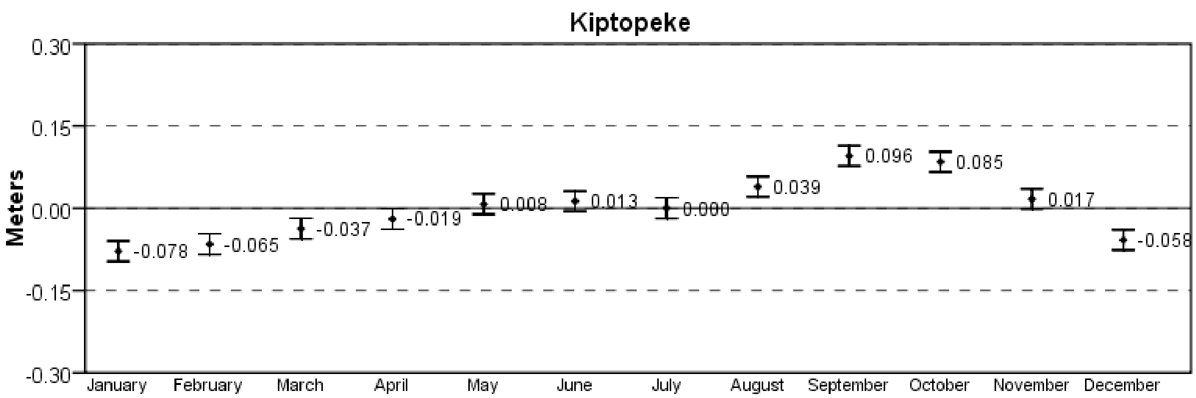
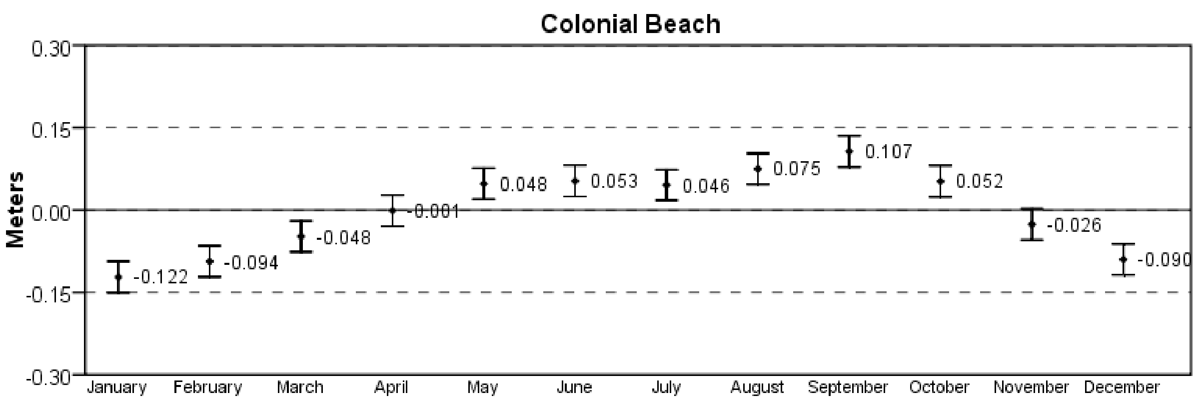
August
September
October
November
December

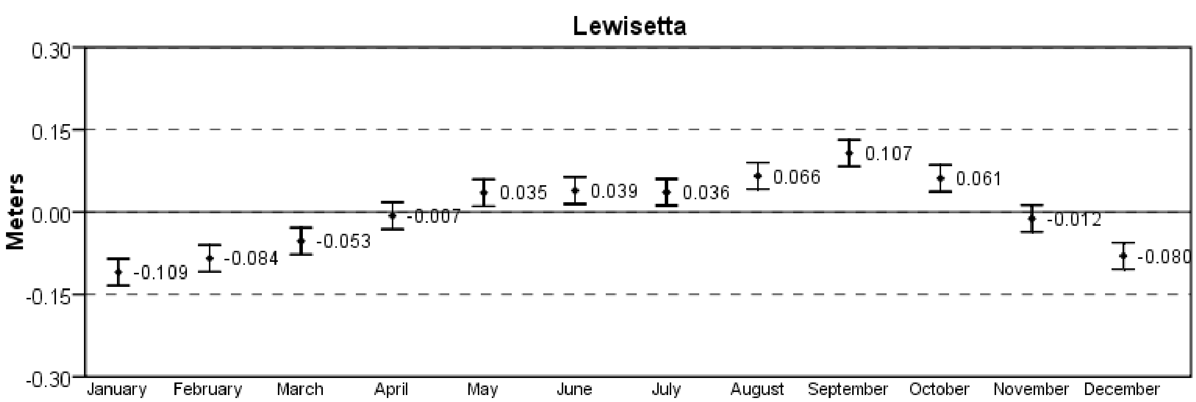

Annapolis
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.124
-0.114
-0.063
0.000
0.042
0.066
0.062
0.082
0.103
0.061
-0.012
-0.101
January
February
March
April
May
June
July
August
September
October
November
December


Solomons Island
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.111
-0.099
-0.053
-0.007
0.035
0.050
0.043
0.070
0.104
0.066
-0.005
-0.093
January
February
March
April
May
June
July
August
September
October
November
December

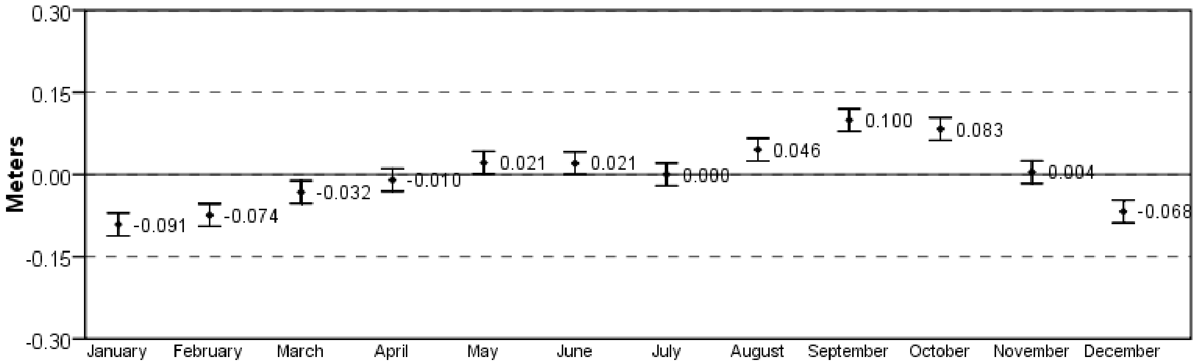

Washington
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.111
-0.091
-0.023
0.024
0.056
0.058
0.037
0.061
0.087
0.044
-0.031
-0.112


Kiptopeke
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.078
-0.065
-0.037
-0.019
0.008
0.013
0.000
0.039
0.096
0.085
0.017
-0.058

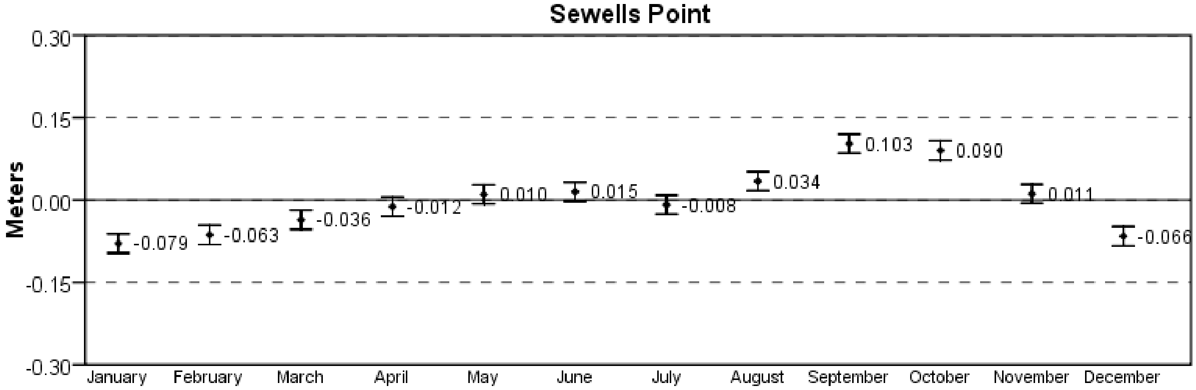

Colonial Beach
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.122
-0.094
-0.048
-0.001
0.048
0.053
0.046
0.075
0.107
0.052
-0.026
-0.090


Lewisetta
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.109
-0.084
-0.053
-0.007
0.035
0.039
0.036
0.066
0.107
0.061
-0.012
-0.080

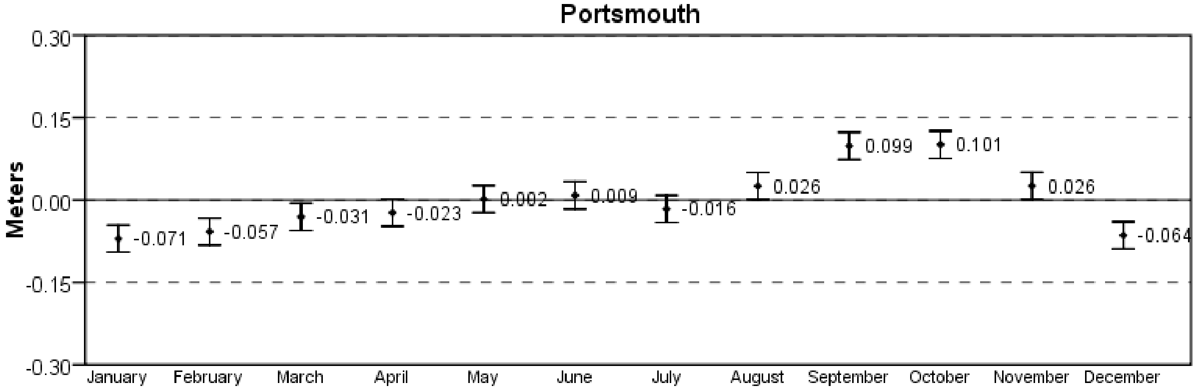
Gloucester Point



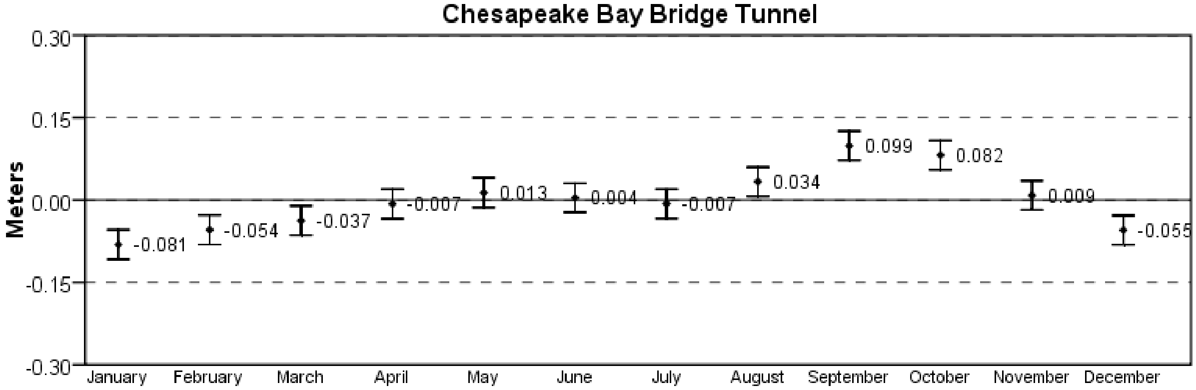
Sewells Point

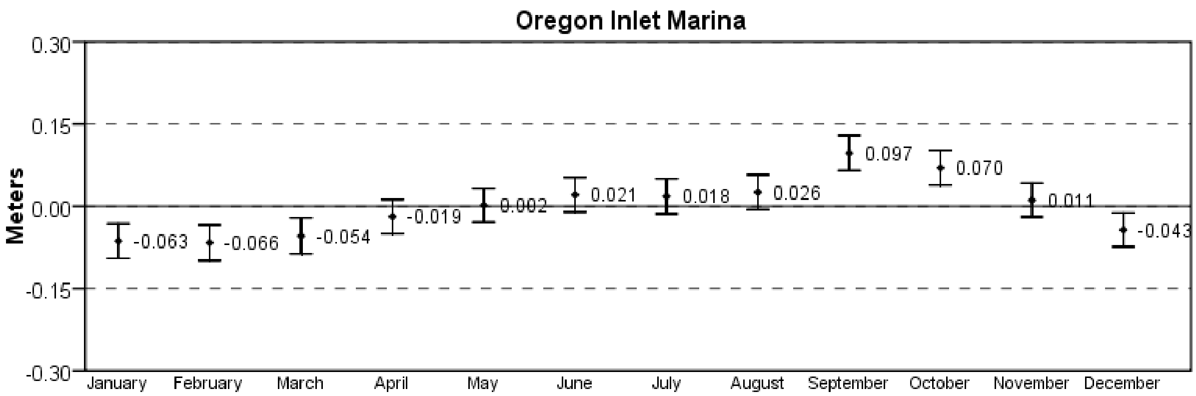


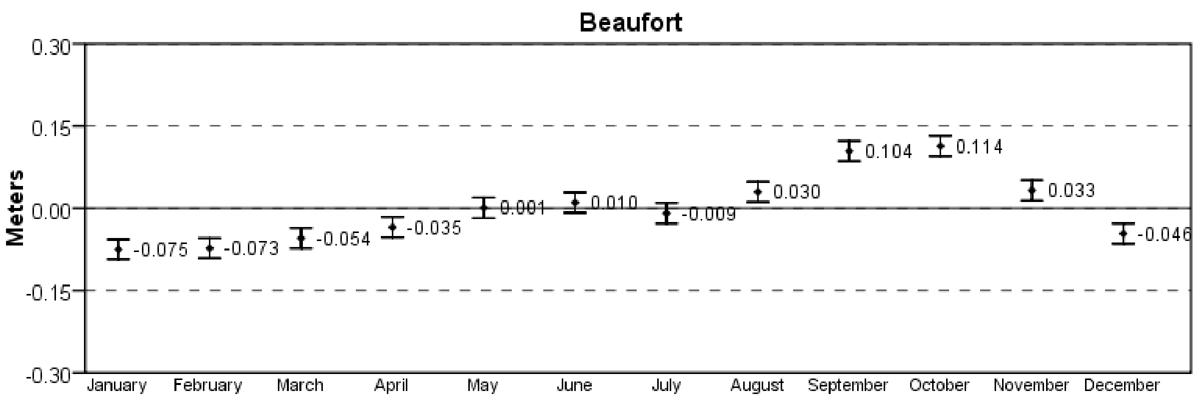
Portsmouth

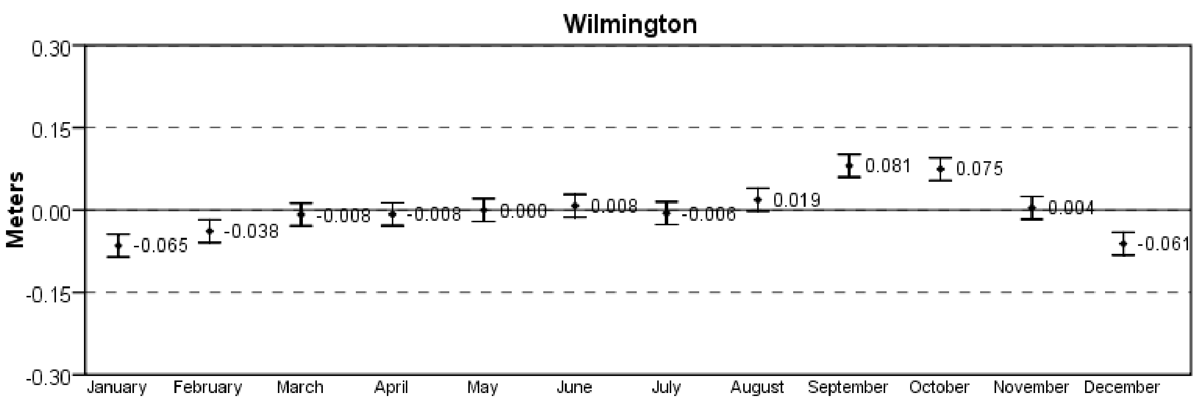


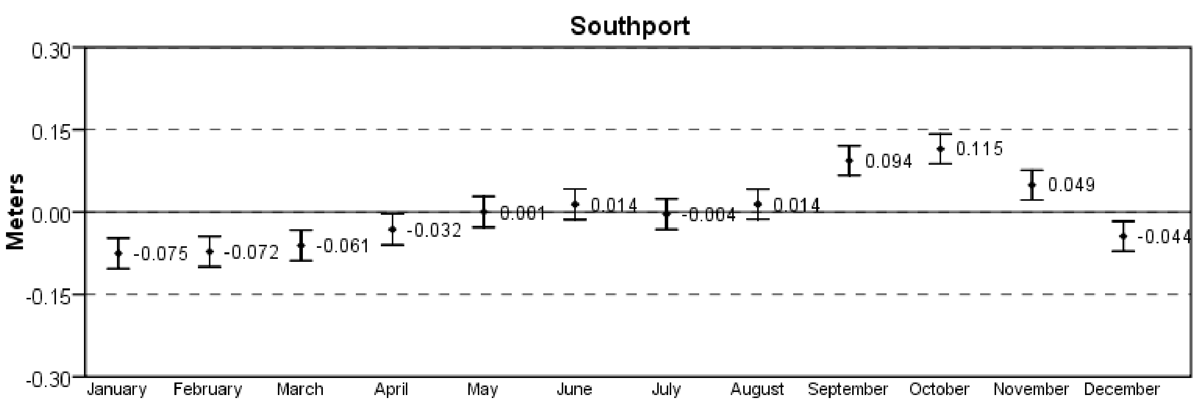
Chesapeake Bay Bridge Tunnel

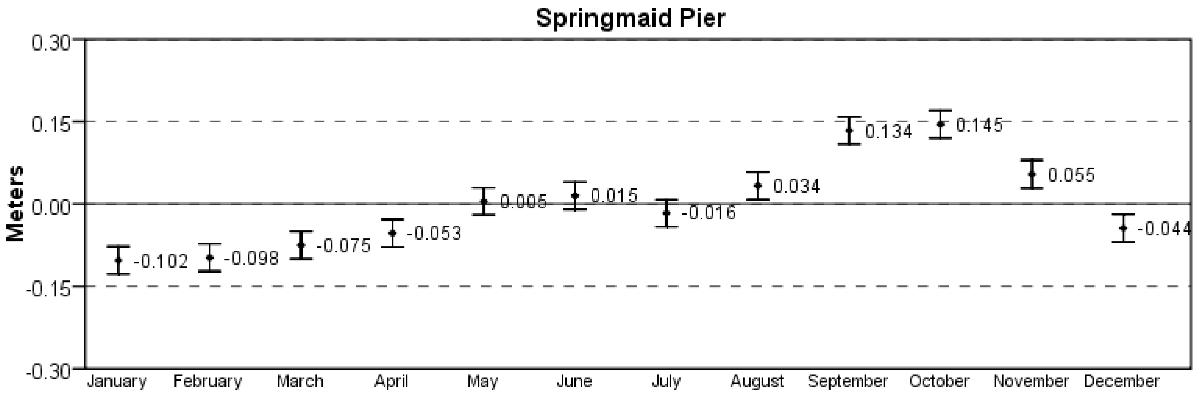


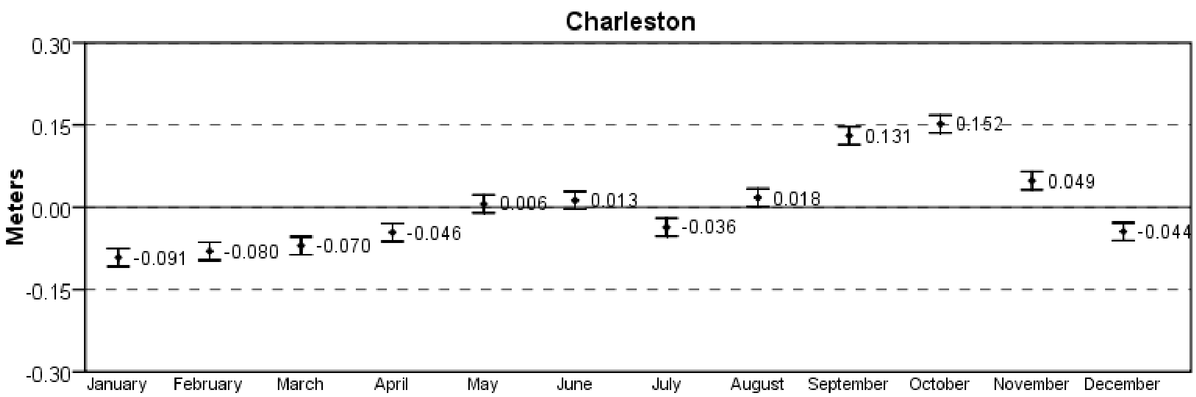

Oregon Inlet Marina
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.063
-0.066
-0.054
-0.019
0.002
0.021
0.018
0.026
0.097
0.070
0.011
-0.043

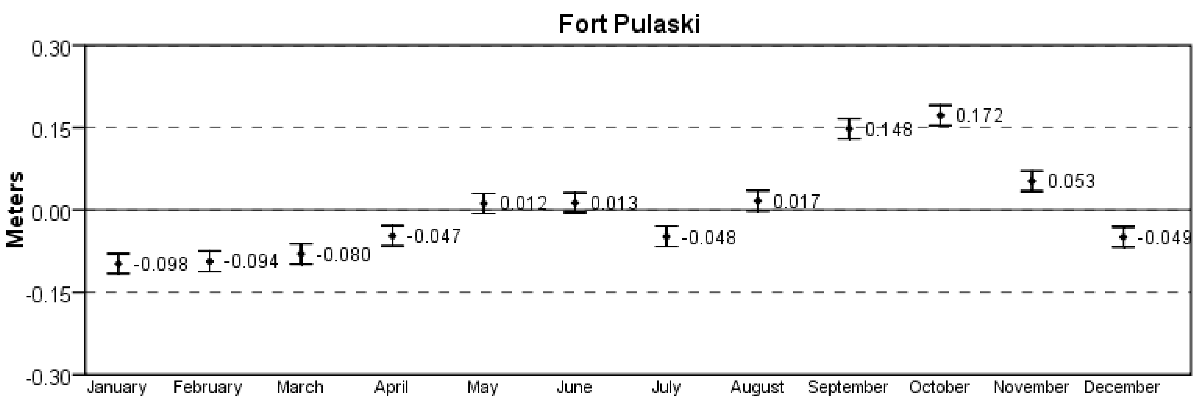

Beaufort
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.075
-0.073
-0.054
-0.035
0.001
0.010
-0.009
0.030
0.104
0.114
0.033
-0.046

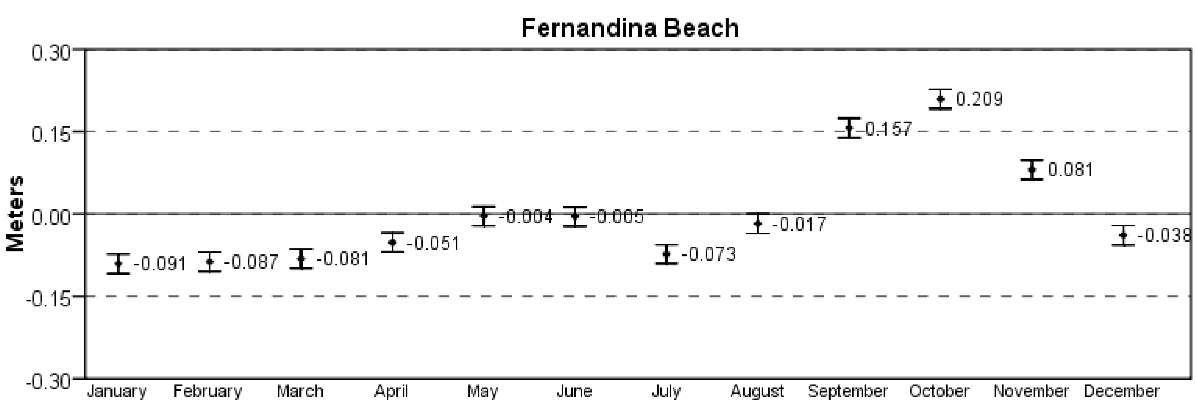

Wilmington
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.065
-0.038
-0.008
-0.008
0.000
0.008
-0.006
0.019
0.081
0.075
0.004
-0.061

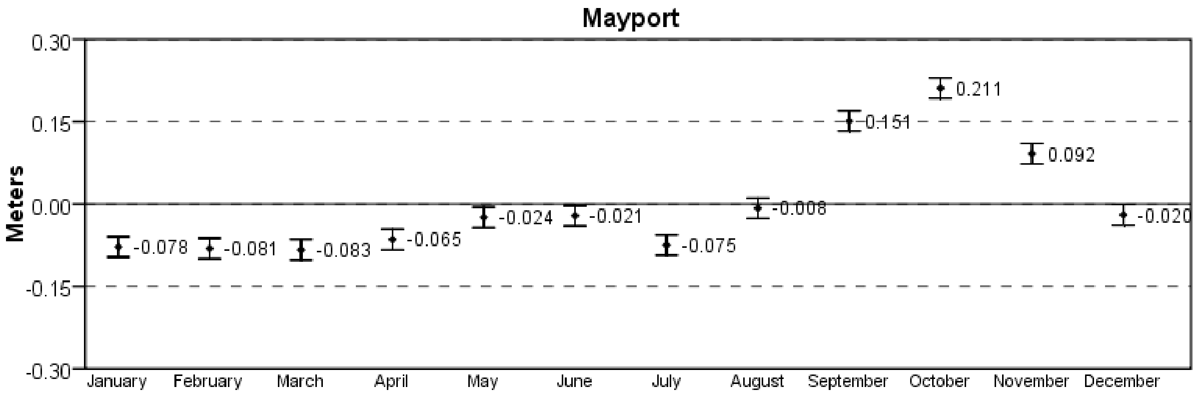

Southport
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.075
-0.072
-0.061
-0.032
0.001
0.014
-0.004
0.014
0.094
0.115
0.049
-0.044

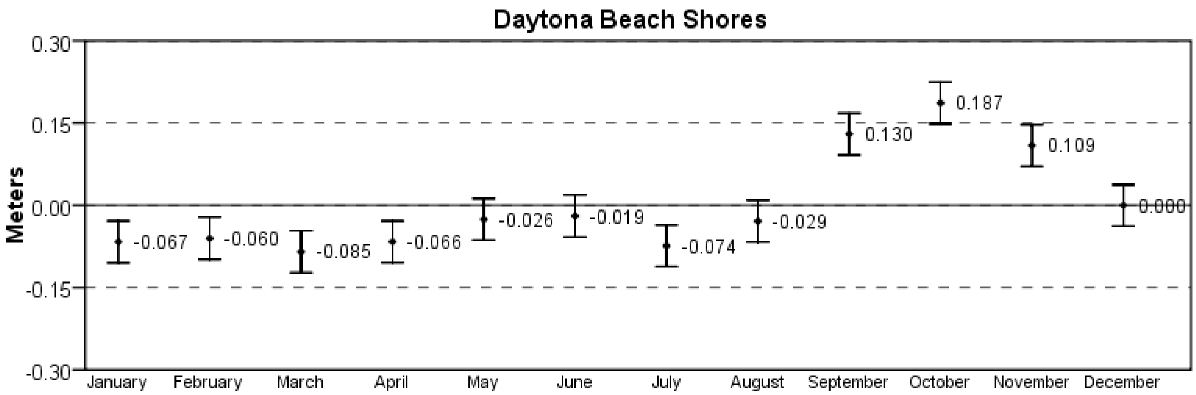

Springmaid Pier
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.102
-0.098
-0.075
-0.053
0.005
0.015
-0.016
0.034
0.134
0.145
0.055
-0.044
January February March April May June July August September October November December


Charleston
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.091
-0.080
-0.070
-0.046
0.006
0.013
-0.036
0.018
0.131
0.152
0.049
-0.044
January February March April May June July August September October November December


Fort Pulaski
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.098
-0.094
-0.080
-0.047
0.012
0.013
-0.048
0.017
0.148
0.172
0.053
-0.049
January February March April May June July August September October November December


Fernandina Beach
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.091
-0.087
-0.081
-0.051
-0.004
-0.005
-0.073
-0.017
0.157
0.209
0.081
-0.038
January February March April May June July August September October November December


Mayport
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.078
-0.081
-0.083
-0.065
-0.024
-0.021
-0.075
-0.008
0.151
0.211
0.092
-0.020
January
February
March
April
May
June
July
August
September
October
November
December


Daytona Beach Shores
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.067
-0.060
-0.085
-0.066
-0.026
-0.019
-0.074
-0.029
0.130
0.187
0.109
0.000
January
February
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April
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June
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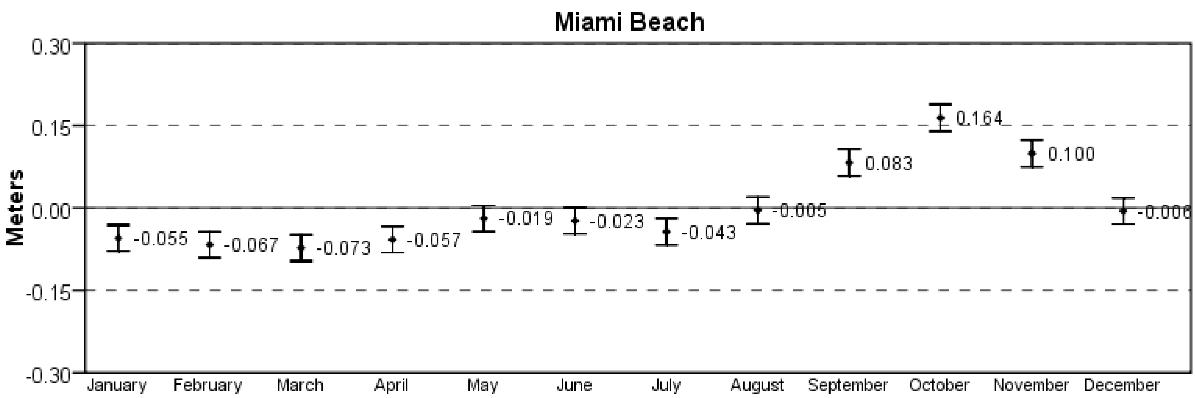
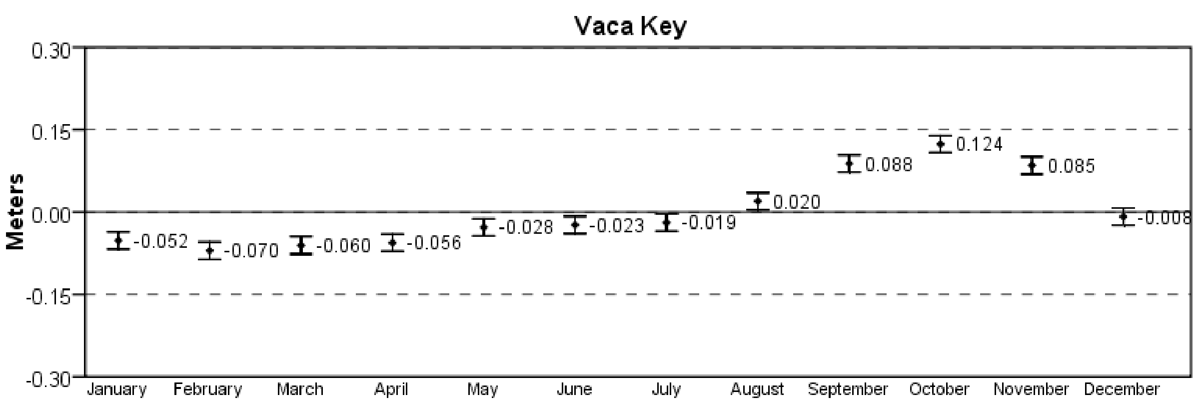
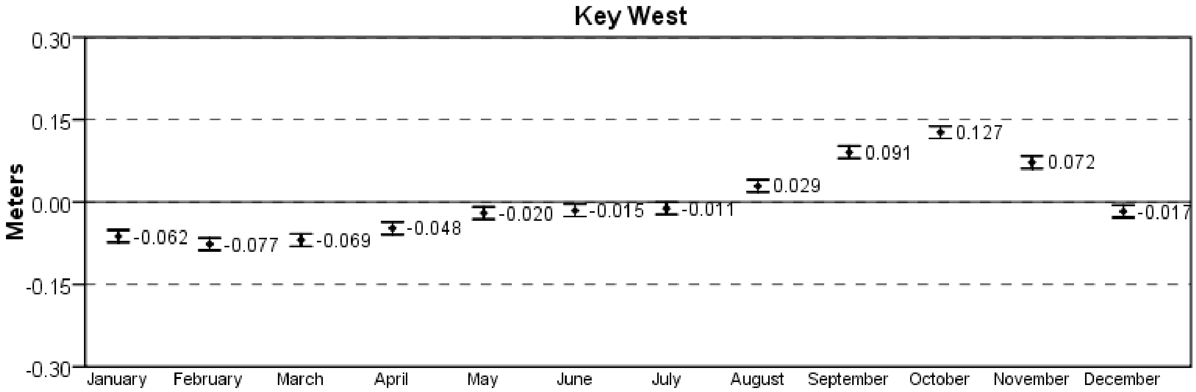
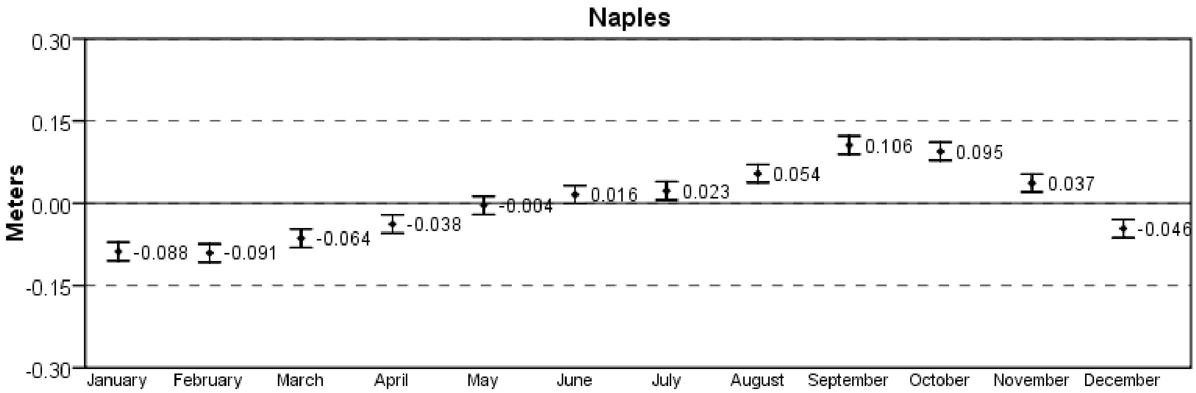
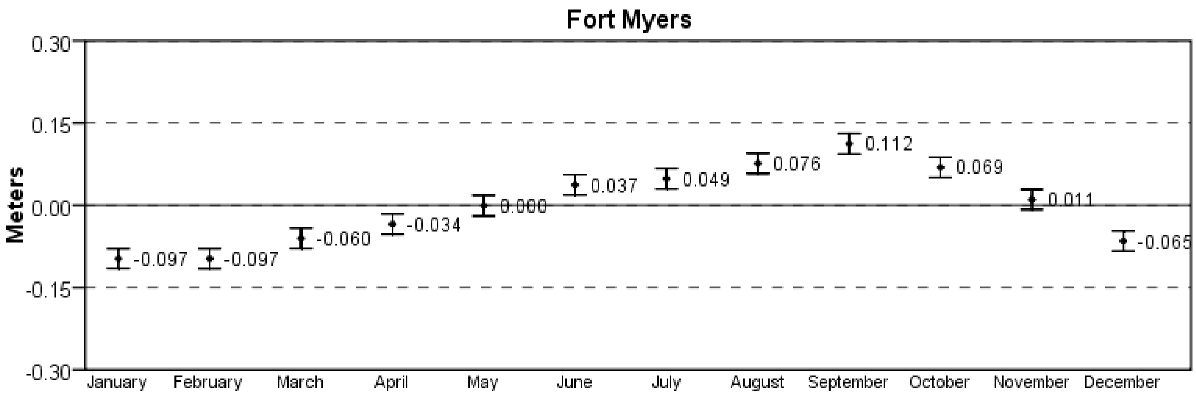
August
September
October
November
December

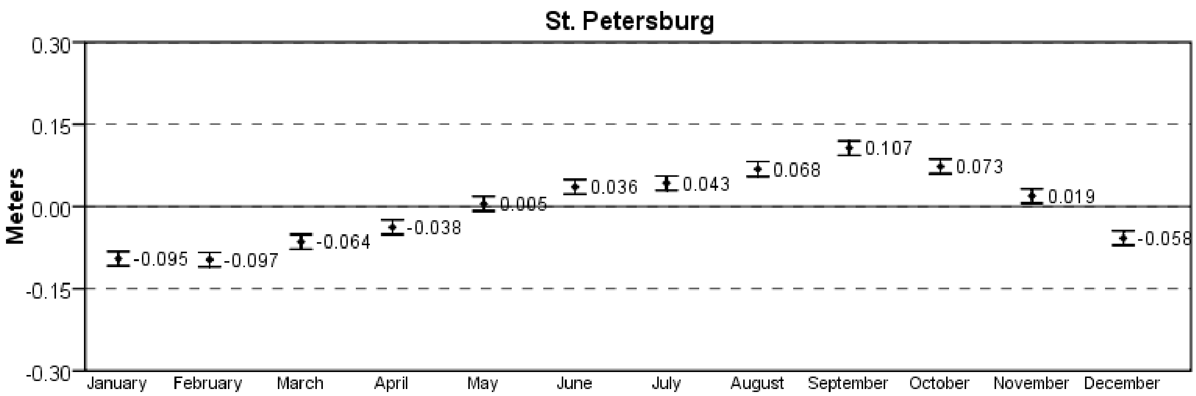

Miami Beach
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.055
-0.067
-0.073
-0.057
-0.019
-0.023
-0.043
-0.005
0.083
0.164
0.100
-0.006
January
February
March
April
May
June
July
August
September
October
November
December

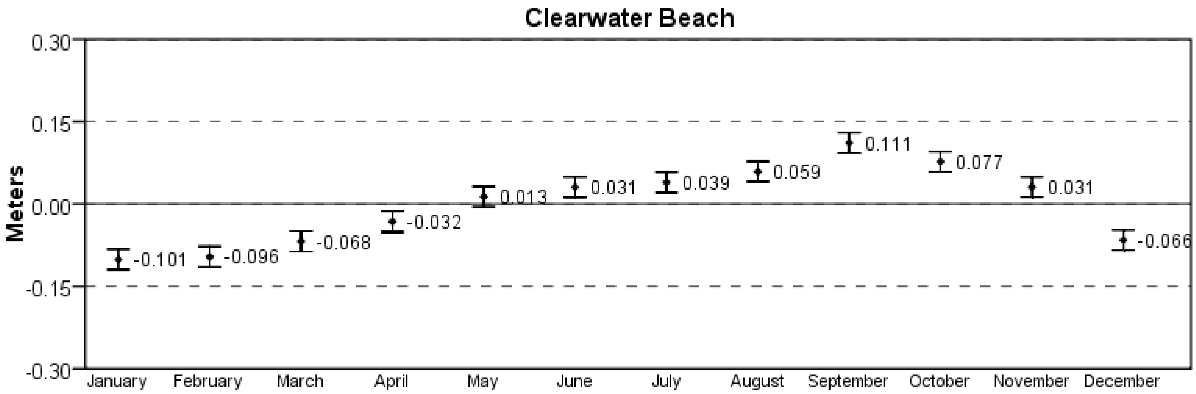

Vaca Key
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.052
-0.070
-0.060
-0.056
-0.028
-0.023
-0.019
0.020
0.088
0.124
0.085
-0.008
January
February
March
April
May
June
July
August
September
October
November
December


Key West
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.062
-0.077
-0.069
-0.048
-0.020
-0.015
-0.011
0.029
0.091
0.127
0.072
-0.017
January February March April May June July August September October November December


Naples
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.088
-0.091
-0.064
-0.038
-0.004
0.016
0.023
0.054
0.106
0.095
0.037
-0.046
January February March April May June July August September October November December


Fort Myers
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.097
-0.097
-0.060
-0.034
0.000
0.037
0.049
0.076
0.112
0.069
0.011
-0.065
January February March April May June July August September October November December


St. Petersburg
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.095
-0.097
-0.064
-0.038
0.005
0.036
0.043
0.068
0.107
0.073
0.019
-0.058
January February March April May June July August September October November December


Clearwater Beach
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.101
-0.096
-0.068
-0.032
0.013
0.031
0.039
0.059
0.111
0.077
0.031
-0.066
January
February
March
April
May
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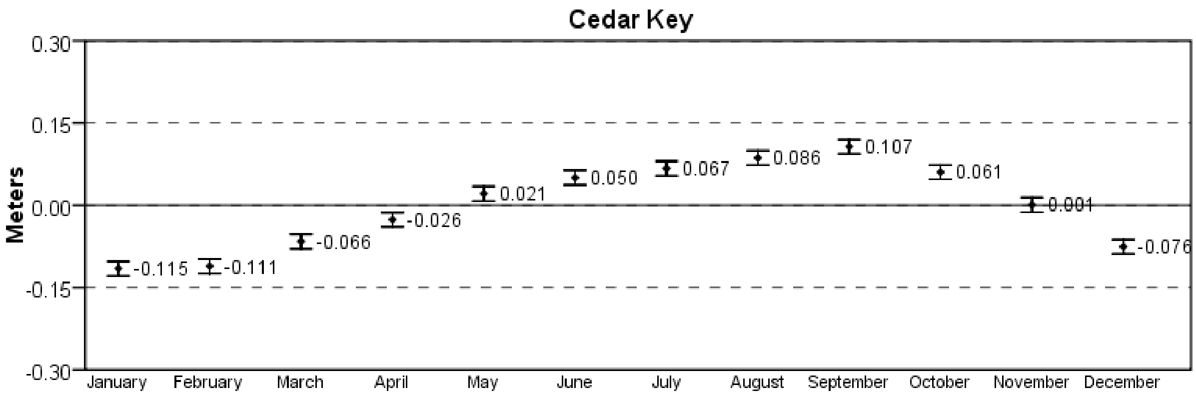
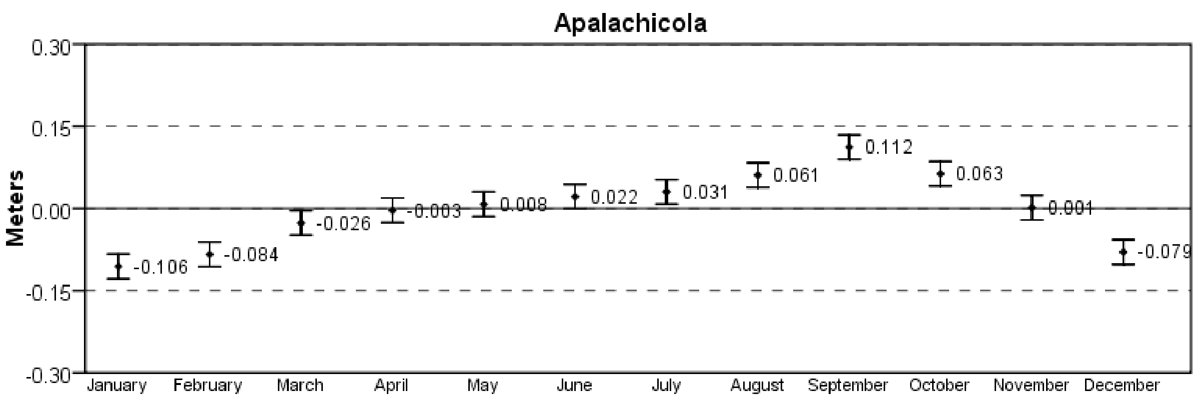
September
October
November
December


Cedar Key
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.115
-0.111
-0.066
-0.026
0.021
0.050
0.067
0.086
0.107
0.061
0.001
-0.076
January
February
March
April
May
June
July
August
September
October
November
December


Apalachicola
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.106
-0.084
-0.026
-0.003
0.008
0.022
0.031
0.061
0.112
0.063
0.001
-0.079
January
February
March
April
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November
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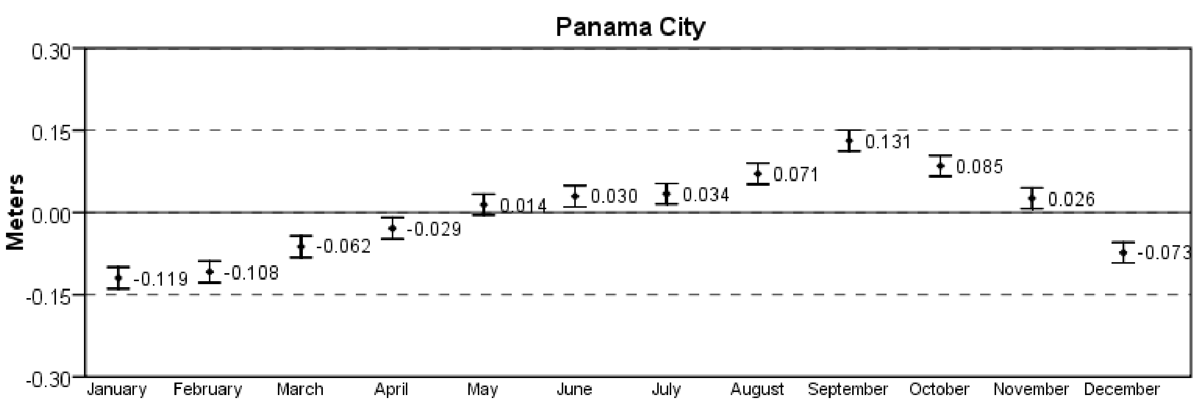
Panama City
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.119
-0.108
-0.062
-0.029
0.014
0.030
0.034
0.071
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0.085
0.026
-0.073
January
February
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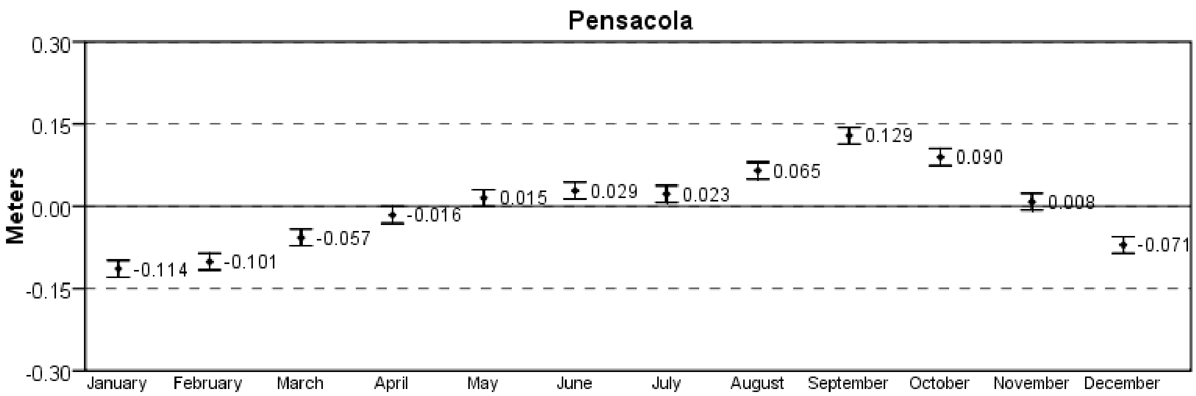
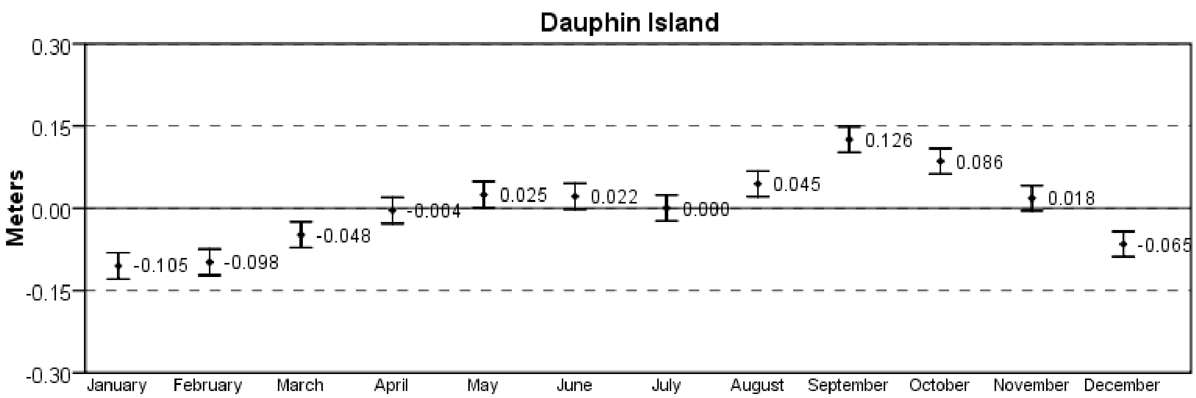
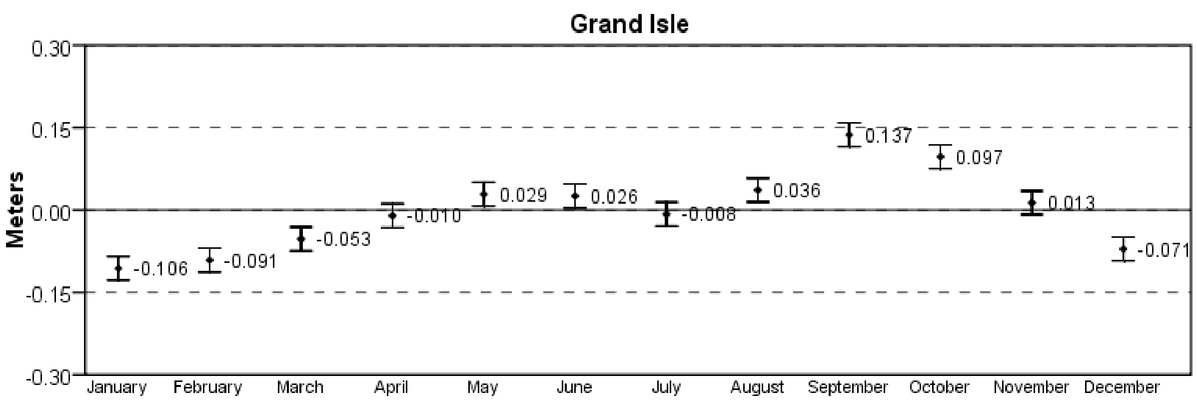
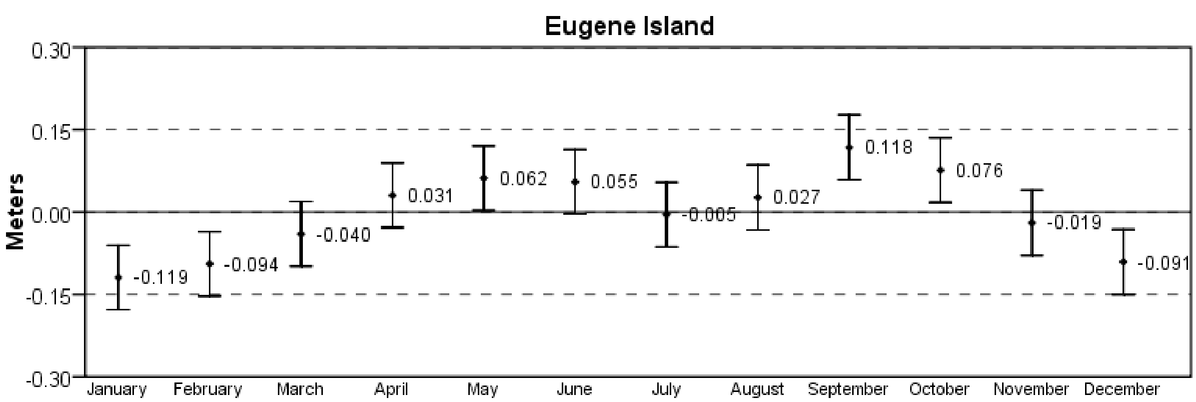
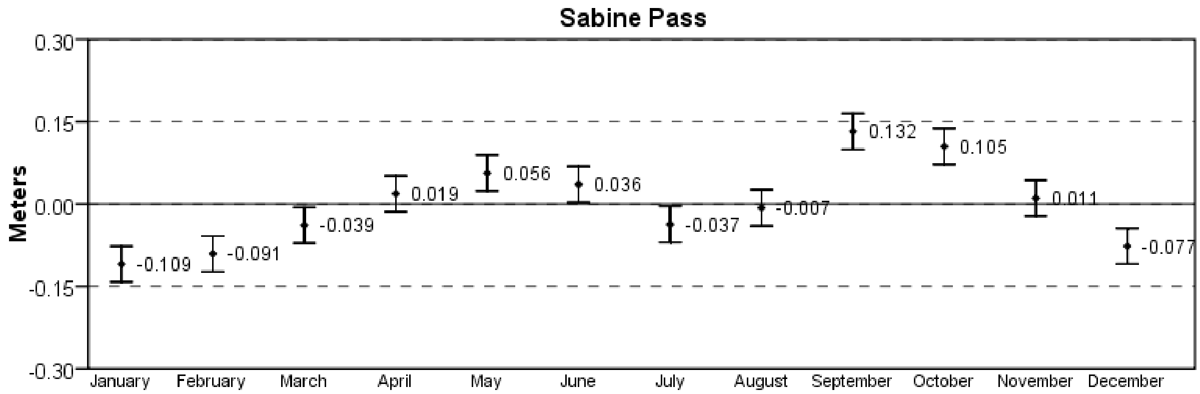
October
November
December


Pensacola
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.114
-0.101
-0.057
-0.016
0.015
0.029
0.023
0.065
0.129
0.090
0.008
-0.071


Dauphin Island
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.105
-0.098
-0.048
-0.004
0.025
0.022
0.000
0.045
0.126
0.086
0.018
-0.065


Grand Isle
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.106
-0.091
-0.053
-0.010
0.029
0.026
-0.008
0.036
0.137
0.097
0.013
-0.071


Eugene Island
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.119
-0.094
-0.040
0.031
0.062
0.055
-0.005
0.027
0.118
0.076
-0.019
-0.091


Sabine Pass
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.109
-0.091
-0.039
0.019
0.056
0.036
-0.037
-0.007
0.132
0.105
0.011
-0.077
January
February
March
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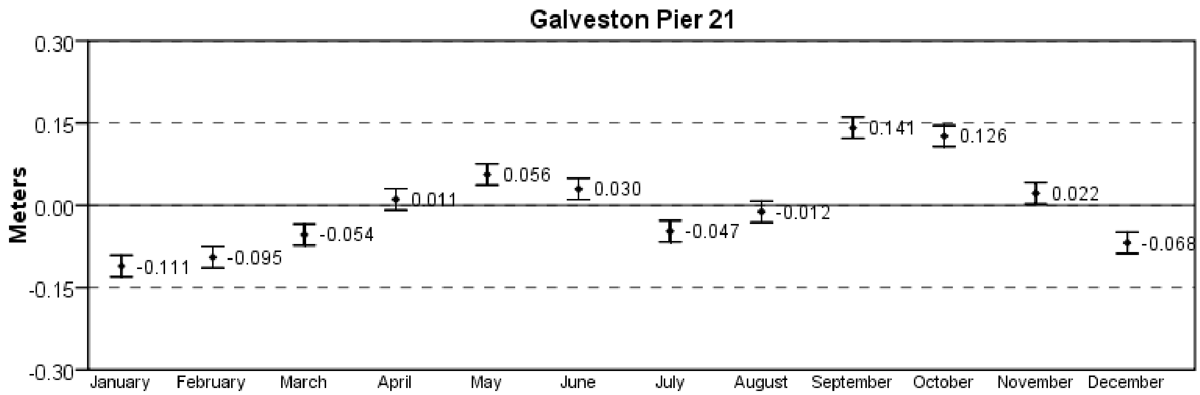
December


Galveston Pier 21
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.111
-0.095
-0.054
0.011
0.056
0.030
-0.047
-0.012
0.141
0.126
0.022
-0.068
January
February
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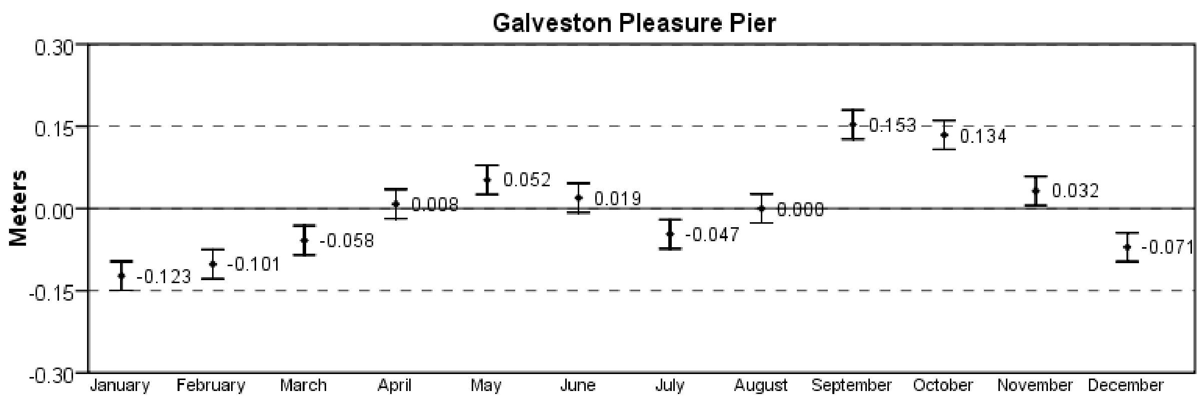
September
October
November
December


Galveston Pleasure Pier
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.123
-0.101
-0.058
0.008
0.052
0.019
-0.047
0.000
0.153
0.134
0.032
-0.071
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October
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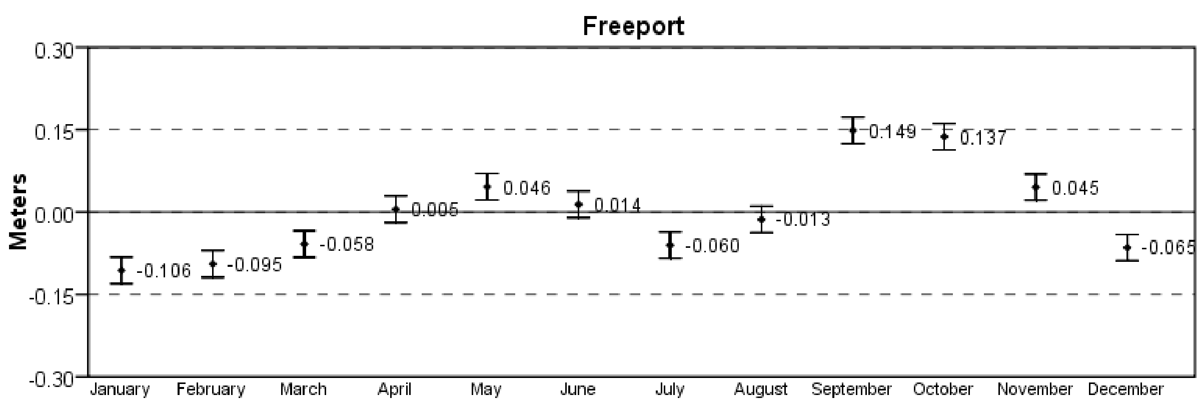
December


Freeport
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.106
-0.095
-0.058
0.005
0.046
0.014
-0.060
-0.013
0.149
0.137
0.045
-0.065
January
February
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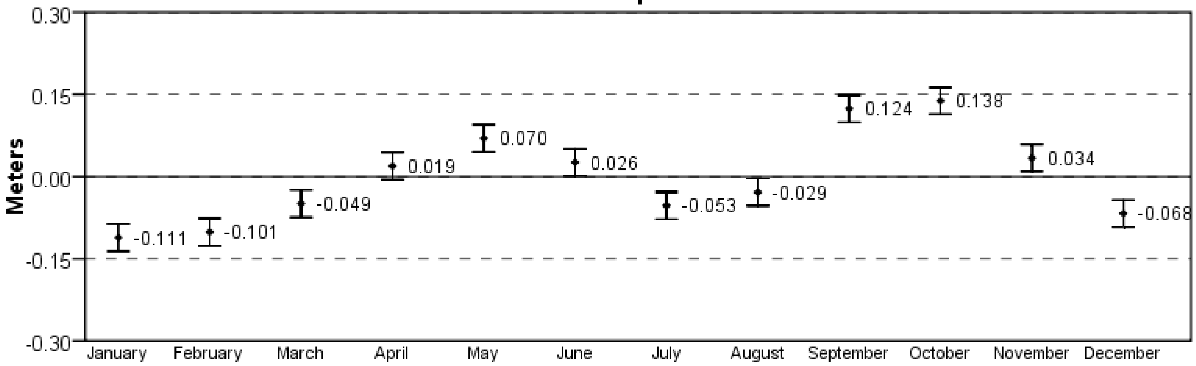
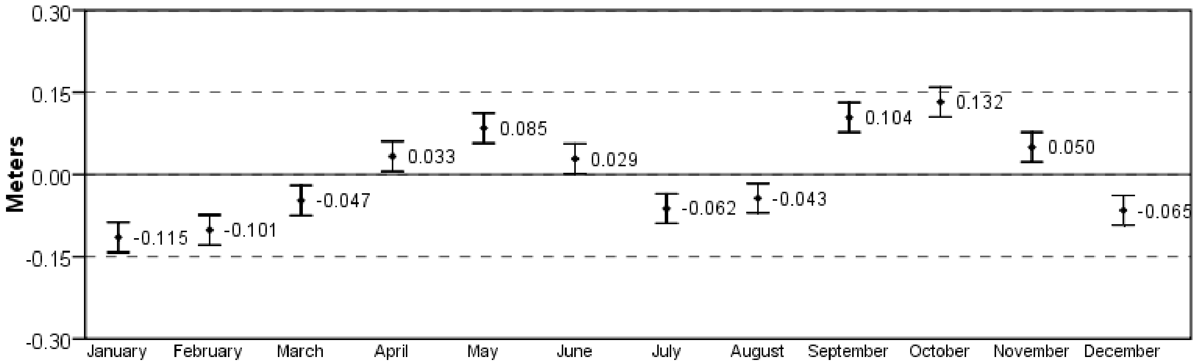
August
September
October
November
December

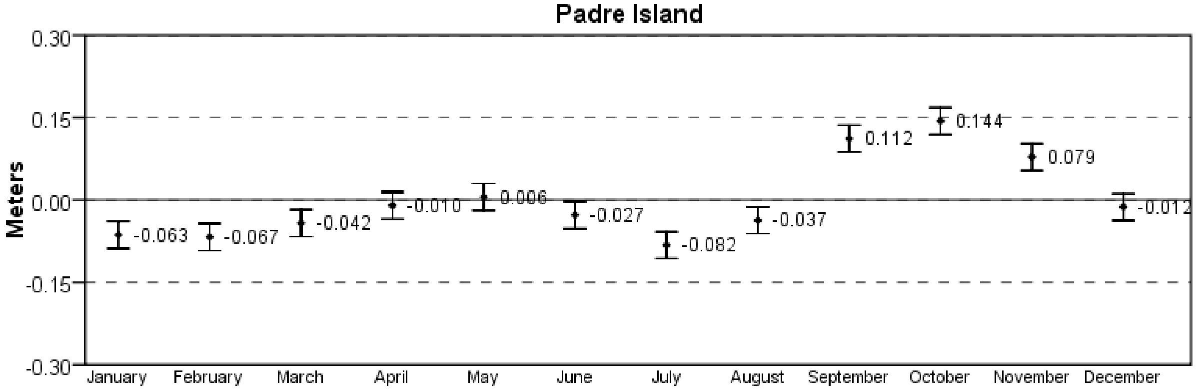
Rockport



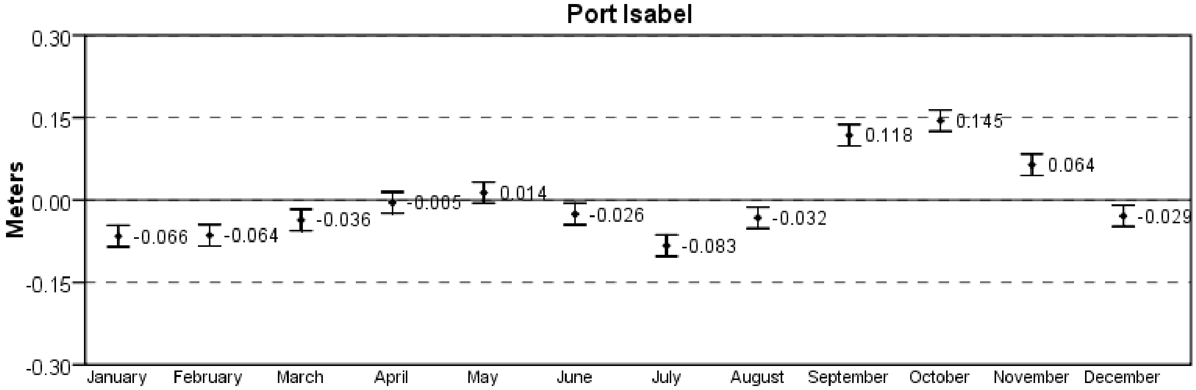
Port Mansfield

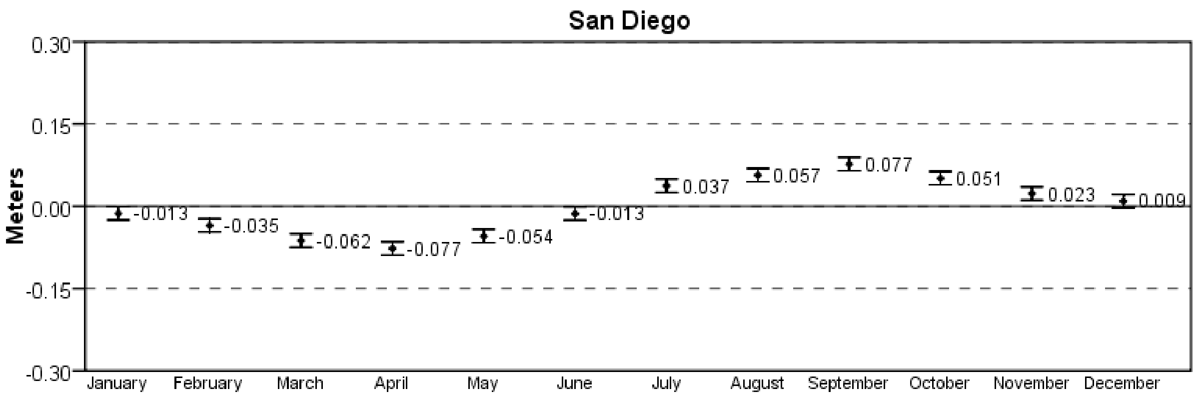


Padre Island



Port Isabel




San Diego
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.013
-0.035
-0.062
-0.077
-0.054
-0.013
0.037
0.057
0.077
0.051
0.023
0.009
January
February
March
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June
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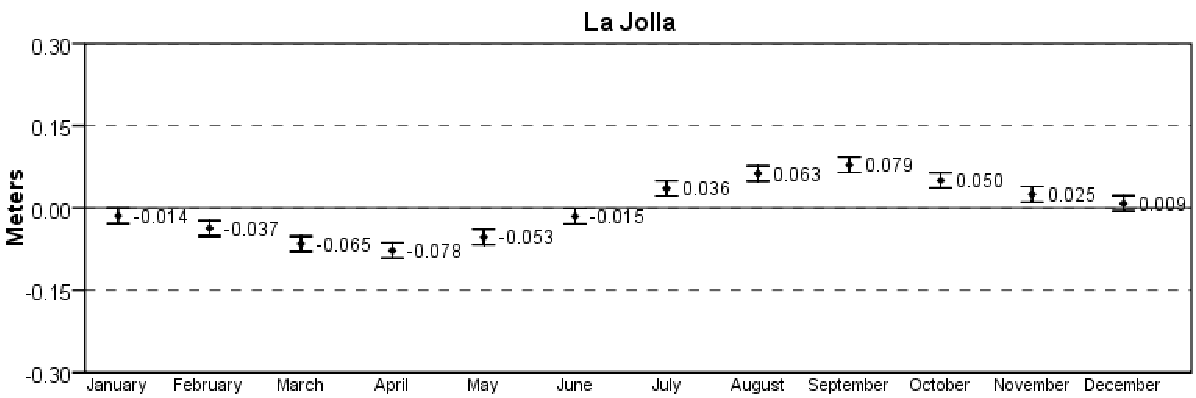
November
December


La Jolla
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.014
-0.037
-0.065
-0.078
-0.053
-0.015
0.036
0.063
0.079
0.050
0.025
0.009
January
February
March
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June
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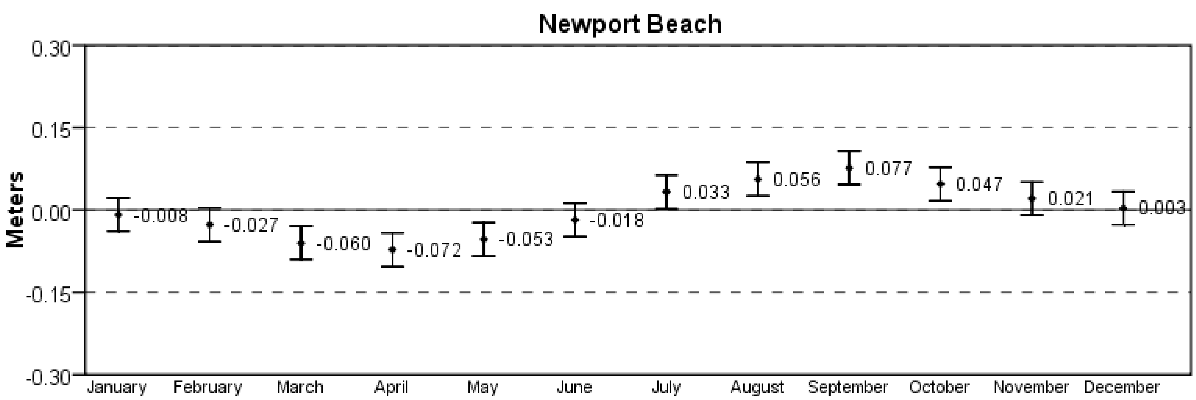
September
October
November
December


Newport Beach
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.008
-0.027
-0.060
-0.072
-0.053
-0.018
0.033
0.056
0.077
0.047
0.021
0.003
January
February
March
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May
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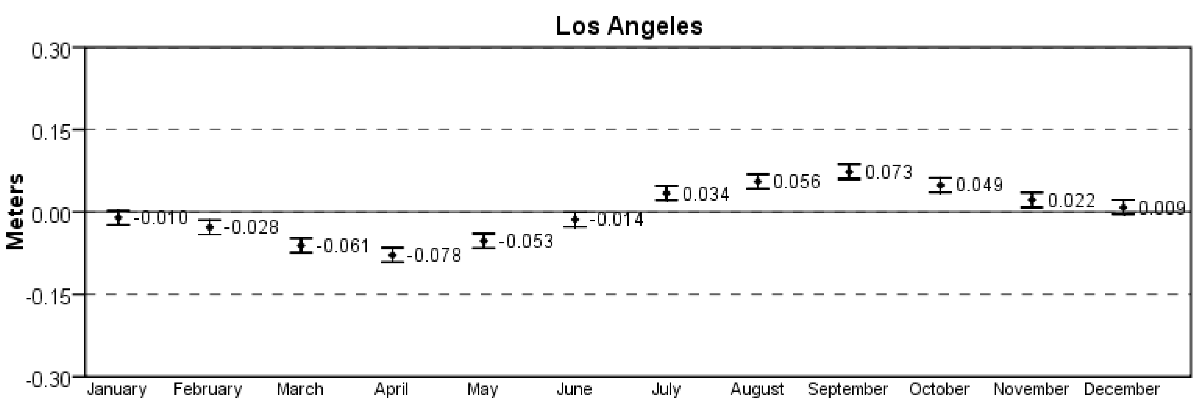
July
August
September
October
November
December


Los Angeles
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.010
-0.028
-0.061
-0.078
-0.053
-0.014
0.034
0.056
0.073
0.049
0.022
0.009
January
February
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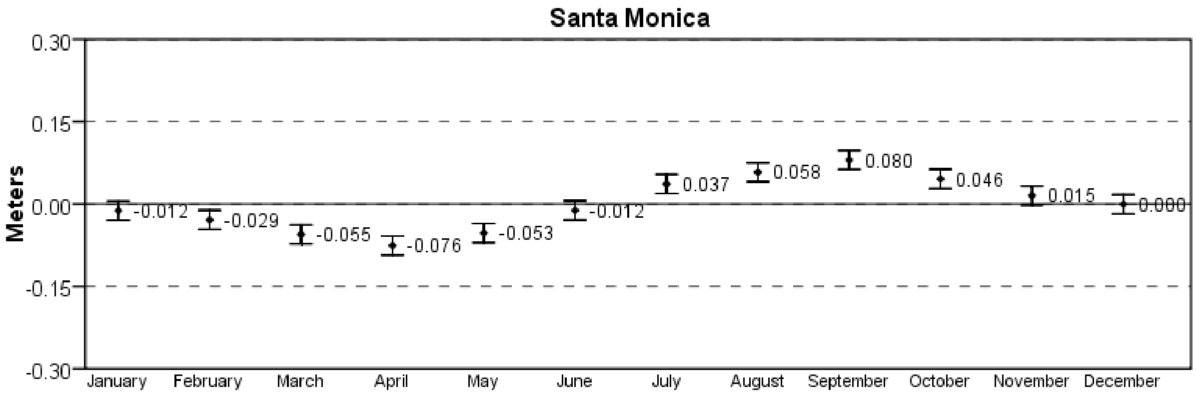
September
October
November
December



Santa Monica
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.012
-0.029
-0.055
-0.076
-0.053
-0.012
0.037
0.058
0.080
0.046
0.015
0.000
January
February
March
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May
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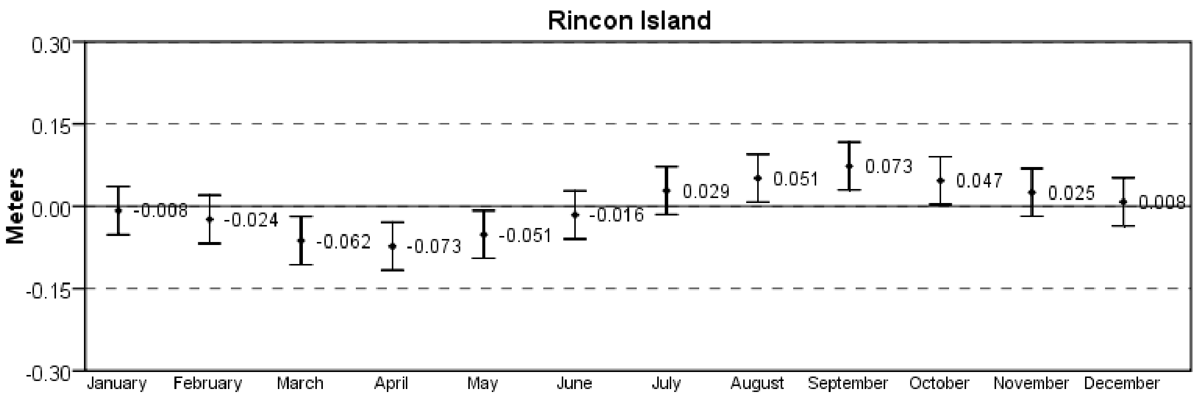
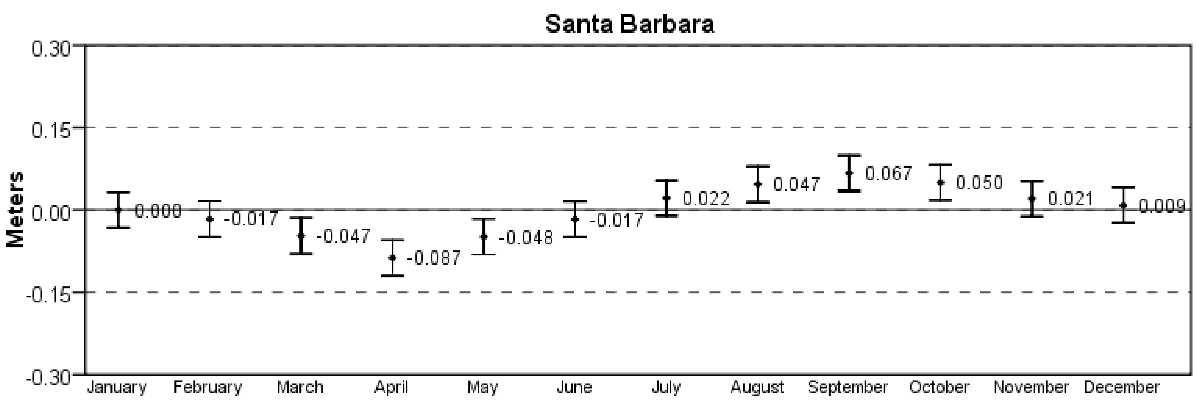
July
August
September
October
November
December



Rincon Island
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.008
-0.024
-0.062
-0.073
-0.051
-0.016
0.029
0.051
0.073
0.047
0.025
0.008
January
February
March
April
May
June
July
August
September
October
November
December



Santa Barbara
Meters
0.30
0.15
0.00
-0.15
-0.30
0.000
-0.017
-0.047
-0.087
-0.048
-0.017
0.022
0.047
0.067
0.050
0.021
0.009
January
February
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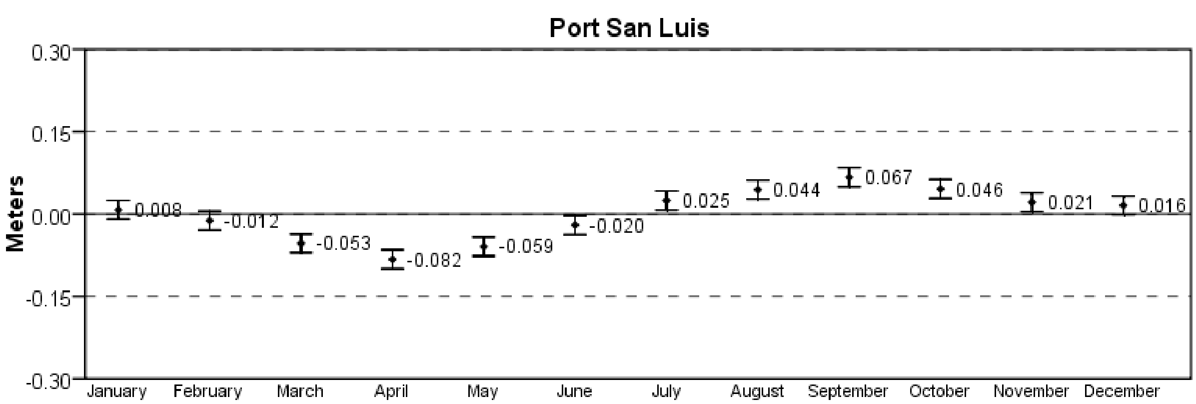
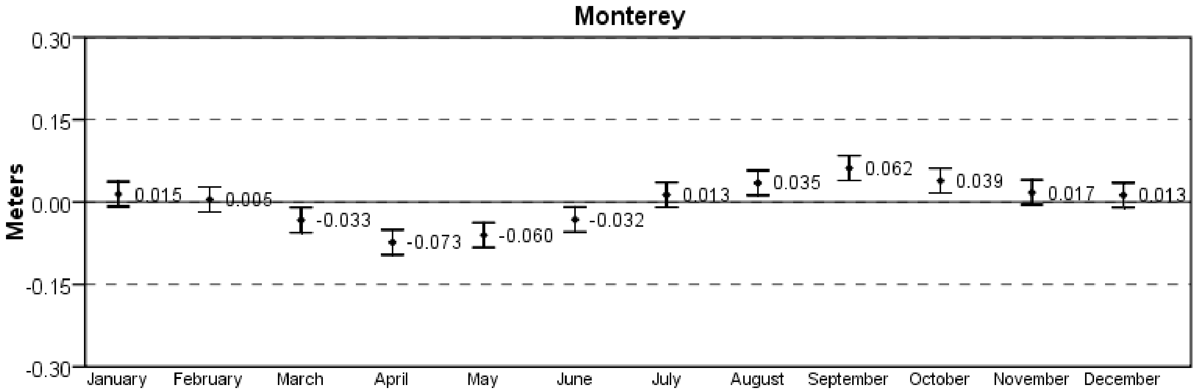
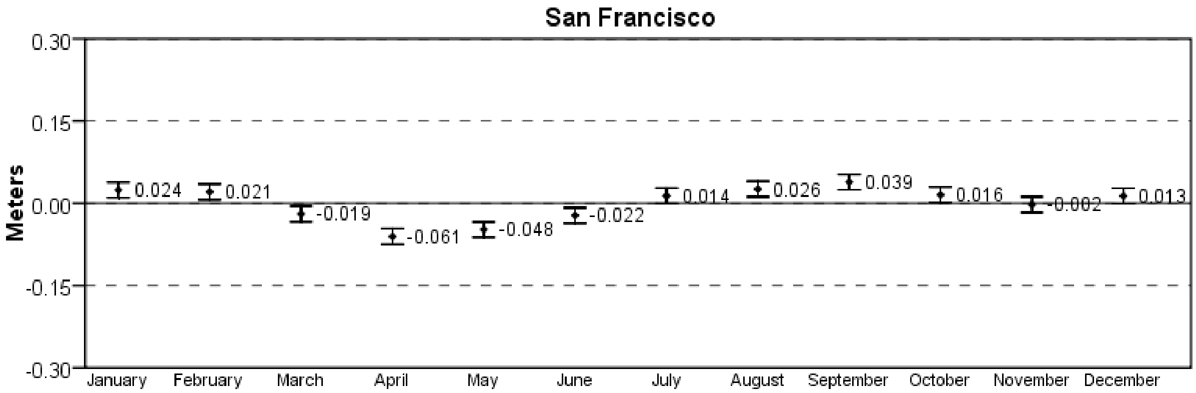
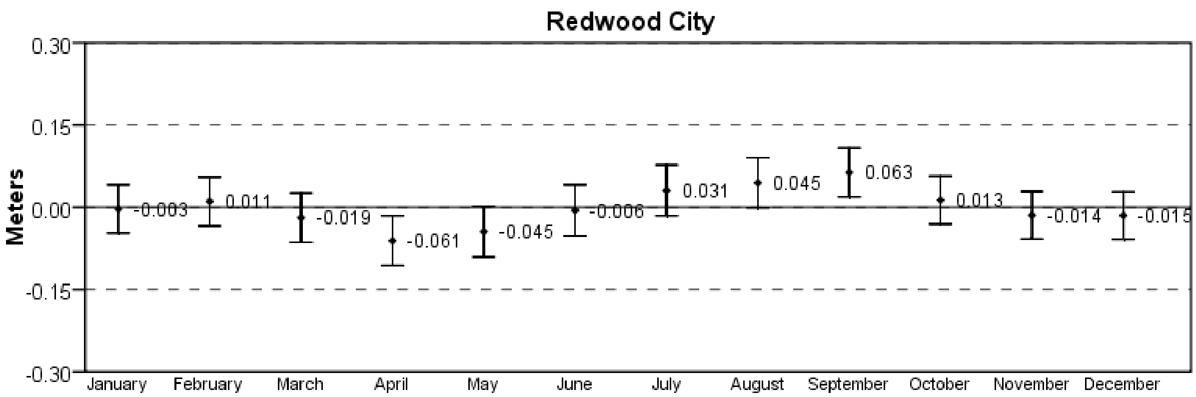
August
September
October
November
December

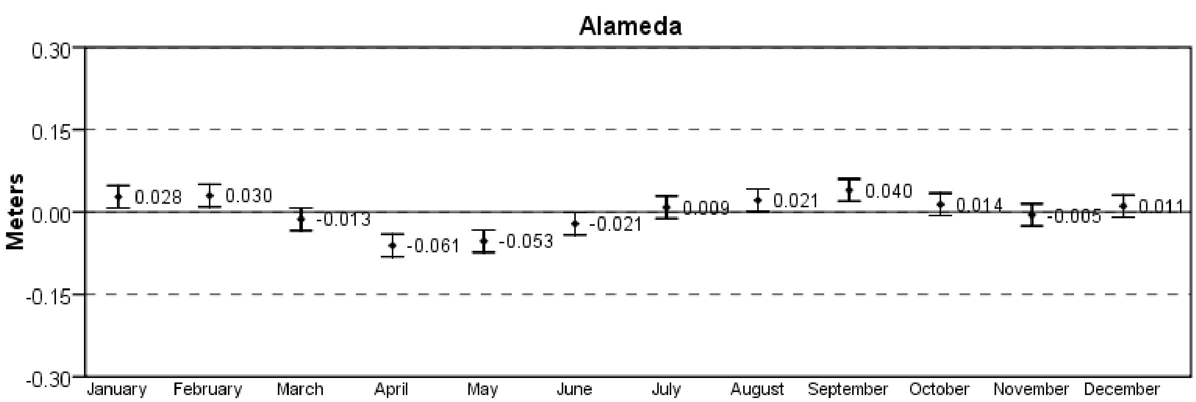


Port San Luis
Meters
0.30
0.15
0.00
-0.15
-0.30
0.008
-0.012
-0.053
-0.082
-0.059
-0.020
0.025
0.044
0.067
0.046
0.021
0.016
January
February
March
April
May
June
July
August
September
October
November
December

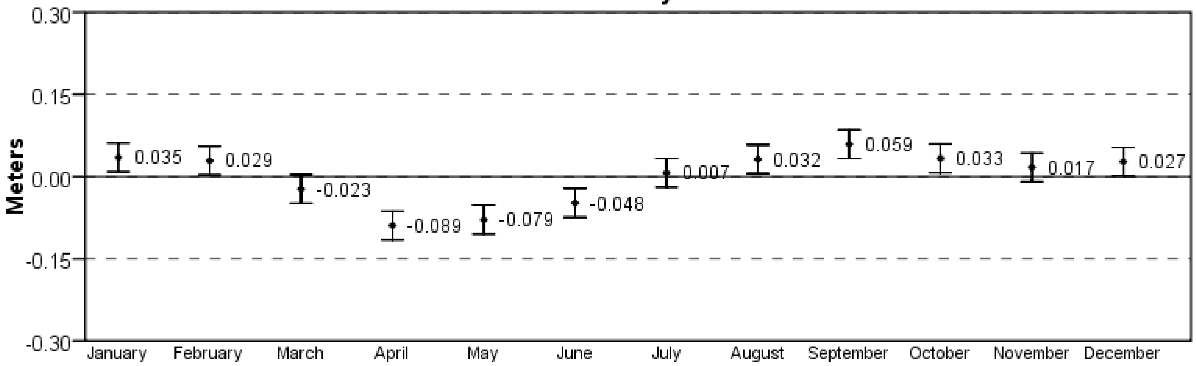

Monterey
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
0.015
0.005
-0.033
-0.073
-0.060
-0.032
0.013
0.035
0.062
0.039
0.017
0.013


San Francisco
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
0.024
0.021
-0.019
-0.061
-0.048
-0.022
0.014
0.026
0.039
0.016
-0.002
0.013

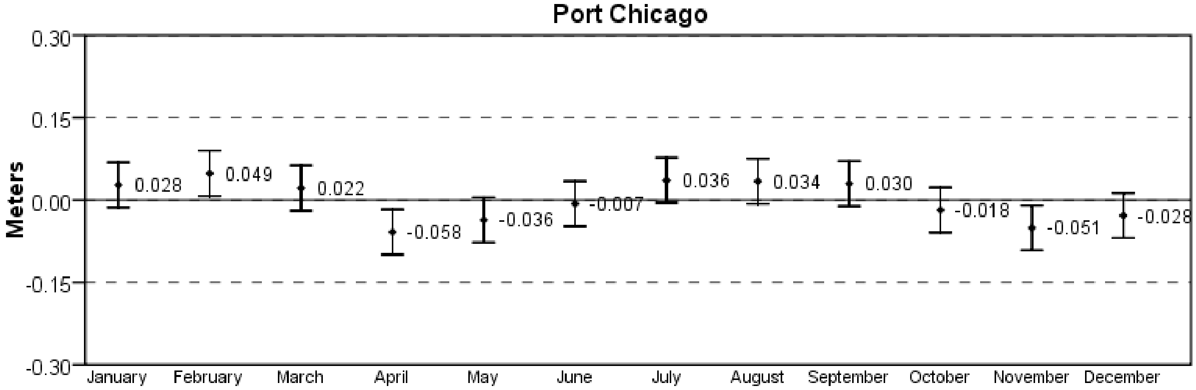

Redwood City
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
-0.003
0.011
-0.019
-0.061
-0.045
-0.006
0.031
0.045
0.063
0.013
-0.014
-0.015


Alameda
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
0.028
0.030
-0.013
-0.061
-0.053
-0.021
0.009
0.021
0.040
0.014
-0.005
0.011

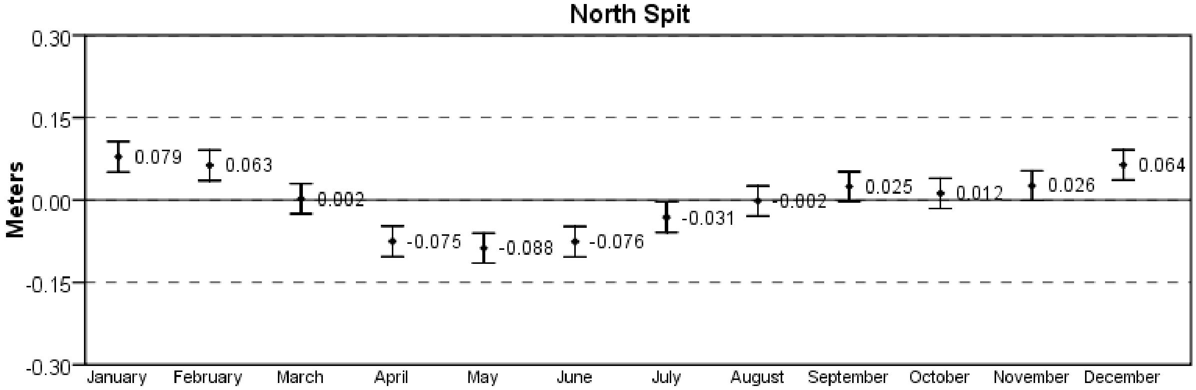
Point Reyes



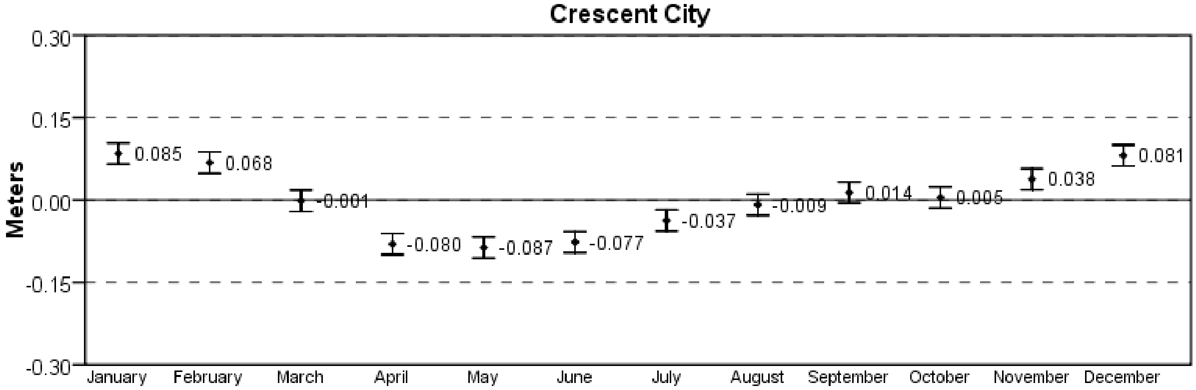
Port Chicago

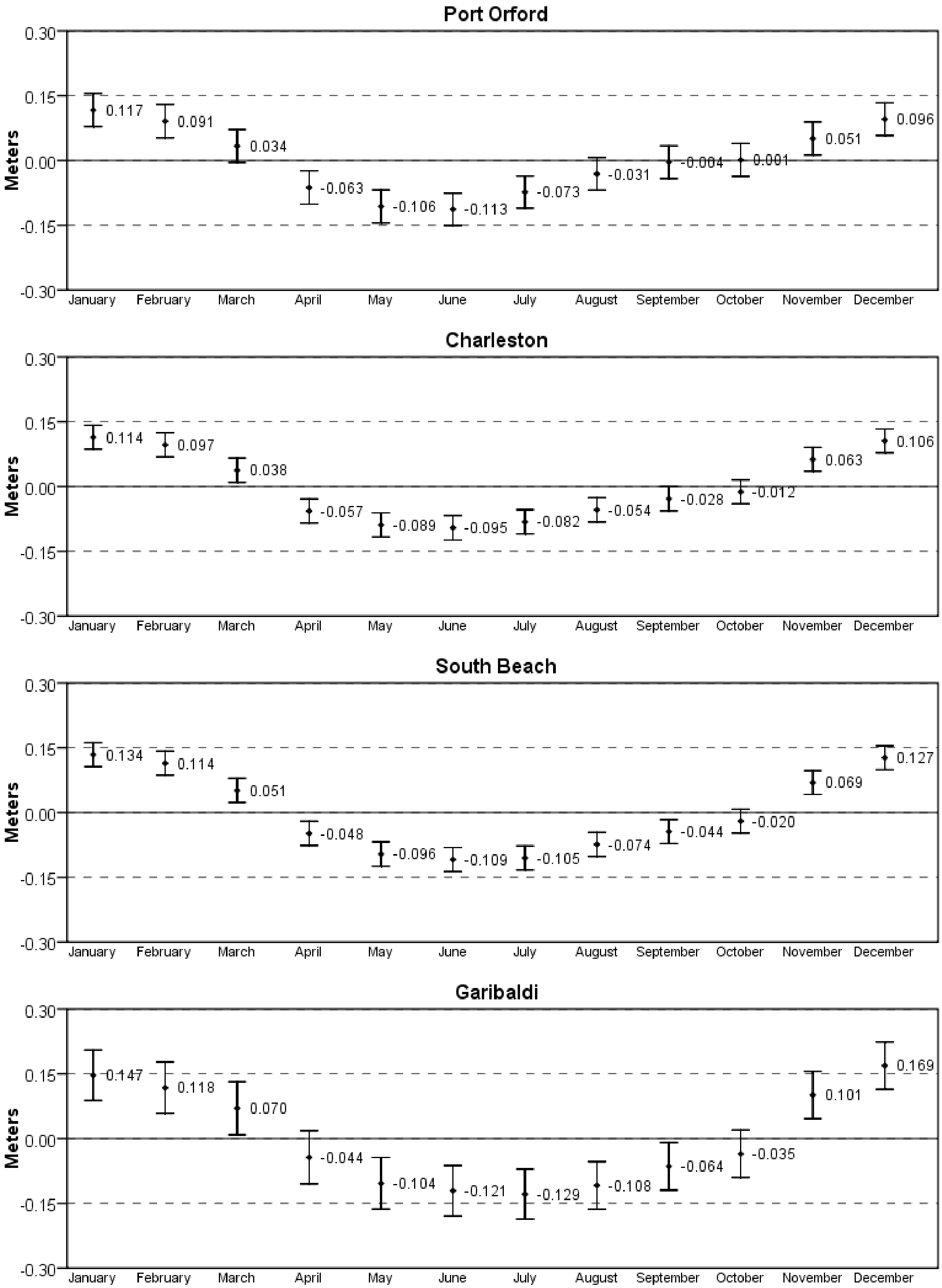


North Spit

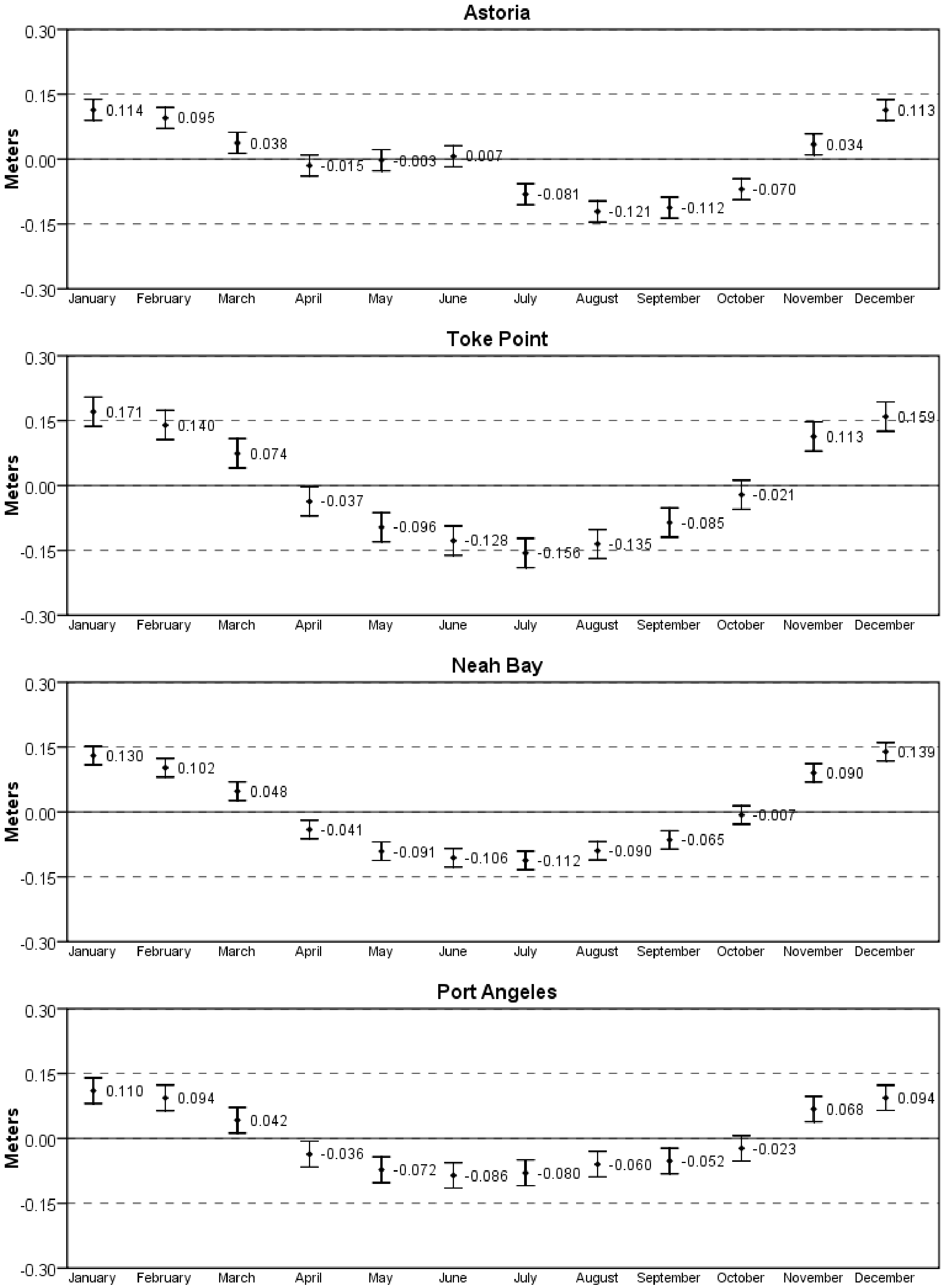


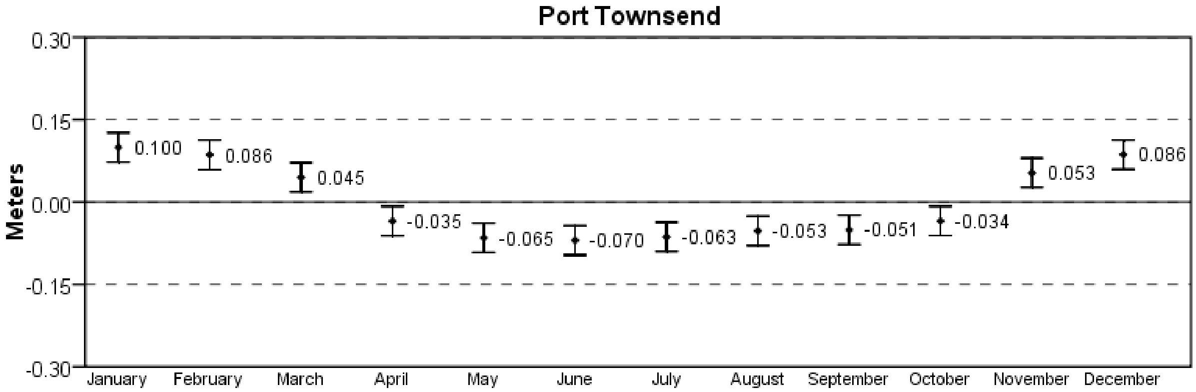
Crescent City

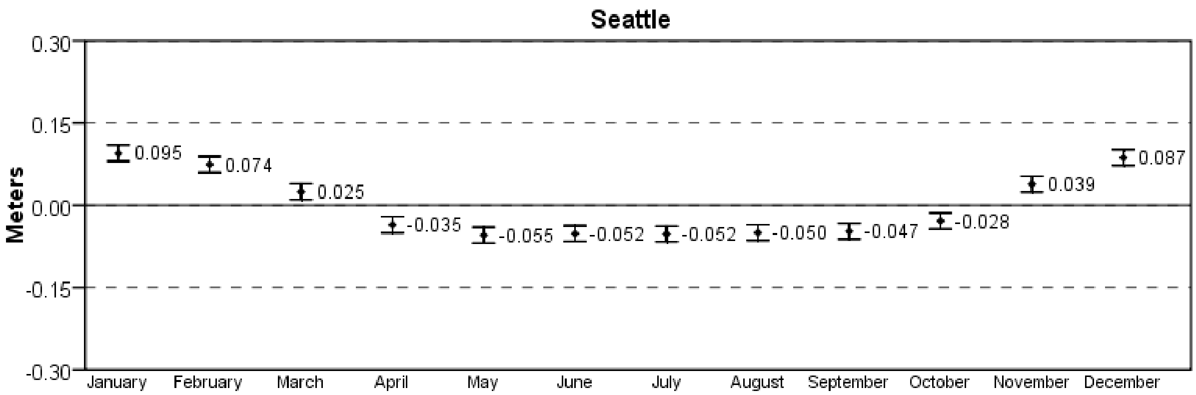




Port Orford
Meters
0.30
0.15
0.00
-0.15
-0.30
0.117
0.091
0.034
-0.063
-0.106
-0.113
-0.073
-0.031
-0.004
0.001
0.051
0.096
January
February
March
April
May
June
July
August
September
October
November
December
Charleston
0.114
0.097
0.038
-0.057
-0.089
-0.095
-0.082
-0.054
-0.028
-0.012
0.063
0.106
South Beach
0.134
0.114
0.051
-0.048
-0.096
-0.109
-0.105
-0.074
-0.044
-0.020
0.069
0.127
Garibaldi
0.147
0.118
0.070
-0.044
-0.104
-0.121
-0.129
-0.108
-0.064
-0.035
0.101
0.169


Astoria
Meters
0.30
0.15
0.00
-0.15
-0.30
January
February
March
April
May
June
July
August
September
October
November
December
0.114
0.095
0.038
-0.015
-0.003
0.007
-0.081
-0.121
-0.112
-0.070
0.034
0.113
Toke Point
0.171
0.140
0.074
-0.037
-0.096
-0.128
-0.156
-0.135
-0.085
-0.021
0.113
0.159
Neah Bay
0.130
0.102
0.048
-0.041
-0.091
-0.106
-0.112
-0.090
-0.065
-0.007
0.090
0.139
Port Angeles
0.110
0.094
0.042
-0.036
-0.072
-0.086
-0.080
-0.060
-0.052
-0.023
0.068
0.094


Port Townsend
Meters
0.30
0.15
0.00
-0.15
-0.30
0.100
0.086
0.045
-0.035
-0.065
-0.070
-0.063
-0.053
-0.051
-0.034
0.053
0.086
January
February
March
April
May
June
July
August
September
October
November
December


Seattle
Meters
0.30
0.15
0.00
-0.15
-0.30
0.095
0.074
0.025
-0.035
-0.055
-0.052
-0.052
-0.050
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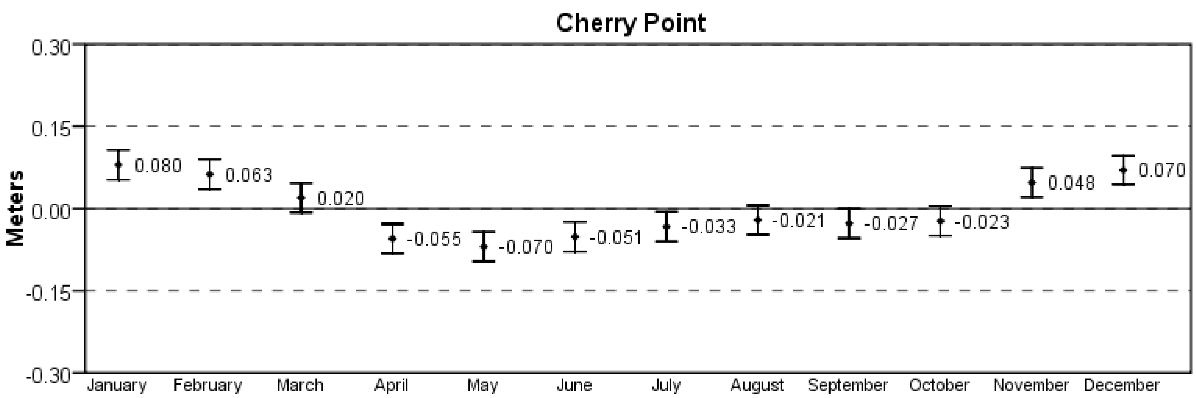
December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-0.021
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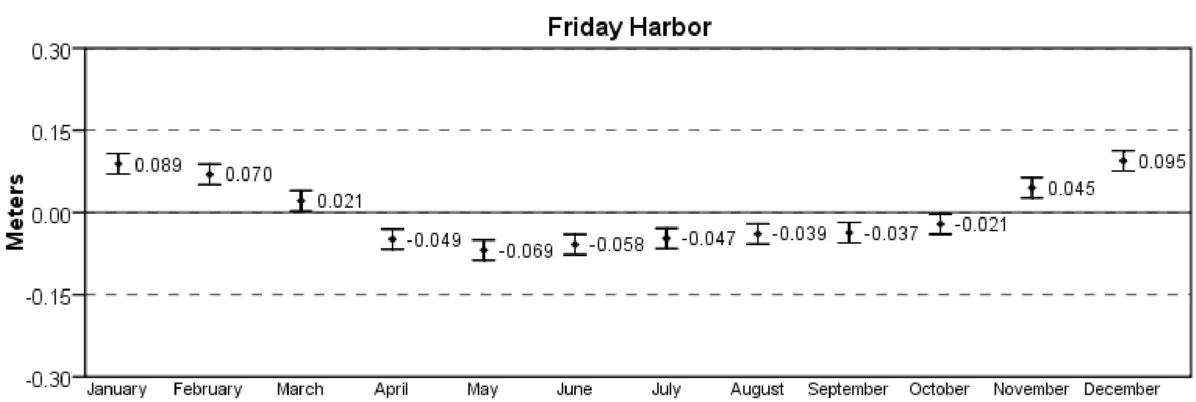
December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-0.039
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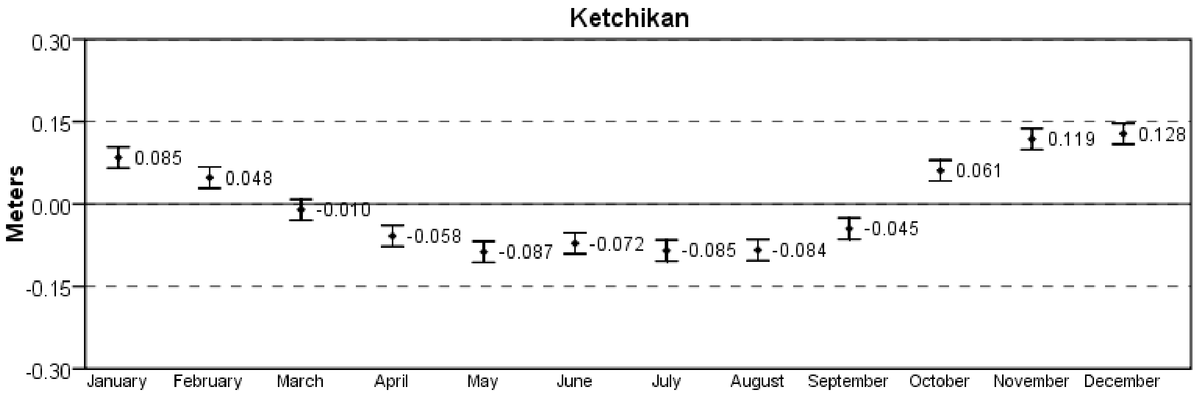
December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Meters
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-0.085
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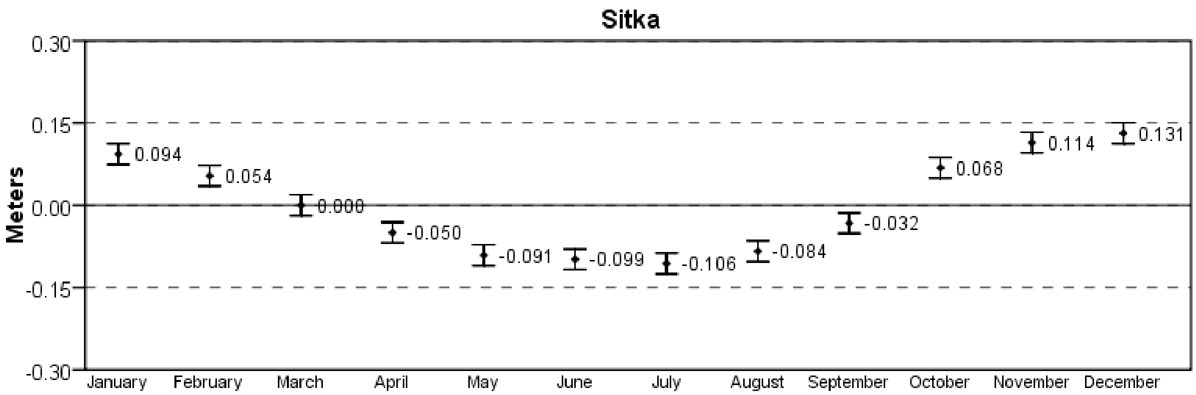
November
December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-0.099
-0.106
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May
June
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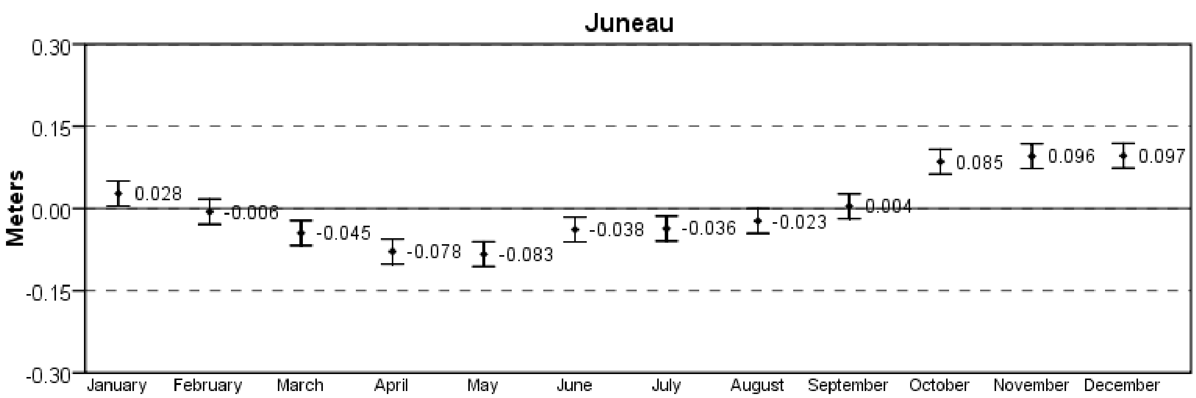
August
September
October
November
December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-0.006
-0.045
-0.078
-0.083
-0.038
-0.036
-0.023
0.004
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0.096
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January
February
March
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September
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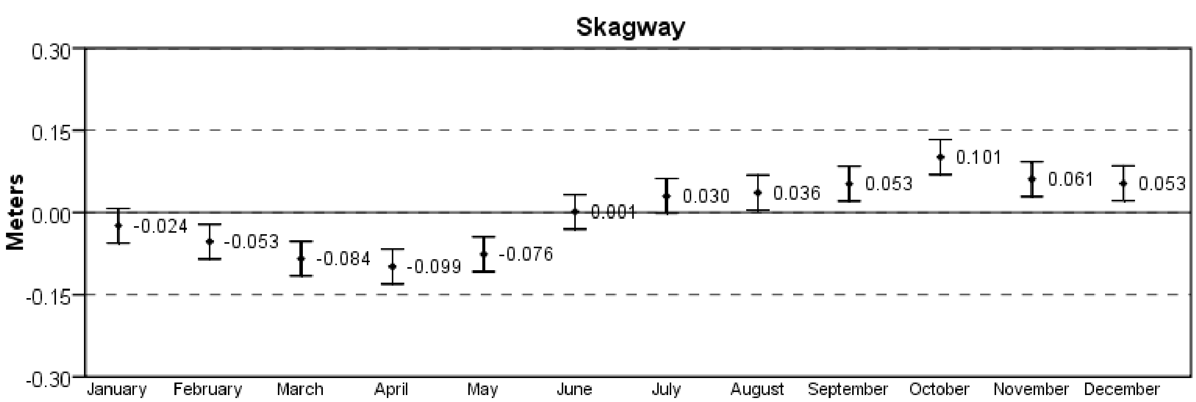
November
December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-0.053
-0.084
-0.099
-0.076
0.001
0.030
0.036
0.053
0.101
0.061
0.053
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March
April
May
June
July
August
September
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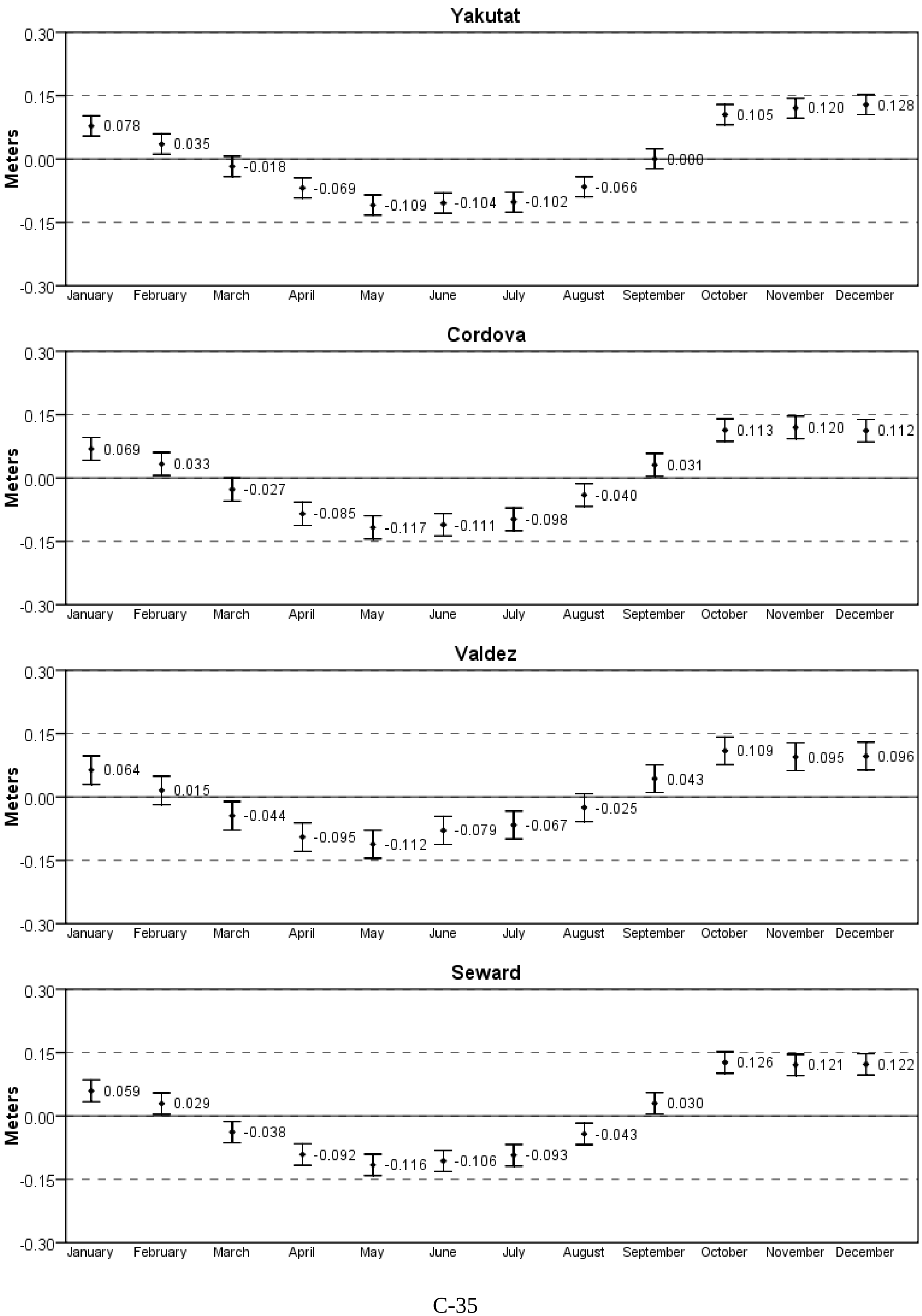
November
December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-0.30
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-0.109
-0.104
-0.102
-0.066
0.000
0.105
0.120
0.128
January February March April May June July August September October November December
Cordova
Meters
0.30
0.15
0.00
-0.15
-0.30
0.069
0.033
-0.027
-0.085
-0.117
-0.111
-0.098
-0.040
0.031
0.113
0.120
0.112
January February March April May June July August September October November December
Valdez
Meters
0.30
0.15
0.00
-0.15
-0.30
0.064
0.015
-0.044
-0.095
-0.112
-0.079
-0.067
-0.025
0.043
0.109
0.095
0.096
January February March April May June July August September October November December
Seward
Meters
0.30
0.15
0.00
-0.15
-0.30
0.059
0.029
-0.038
-0.092
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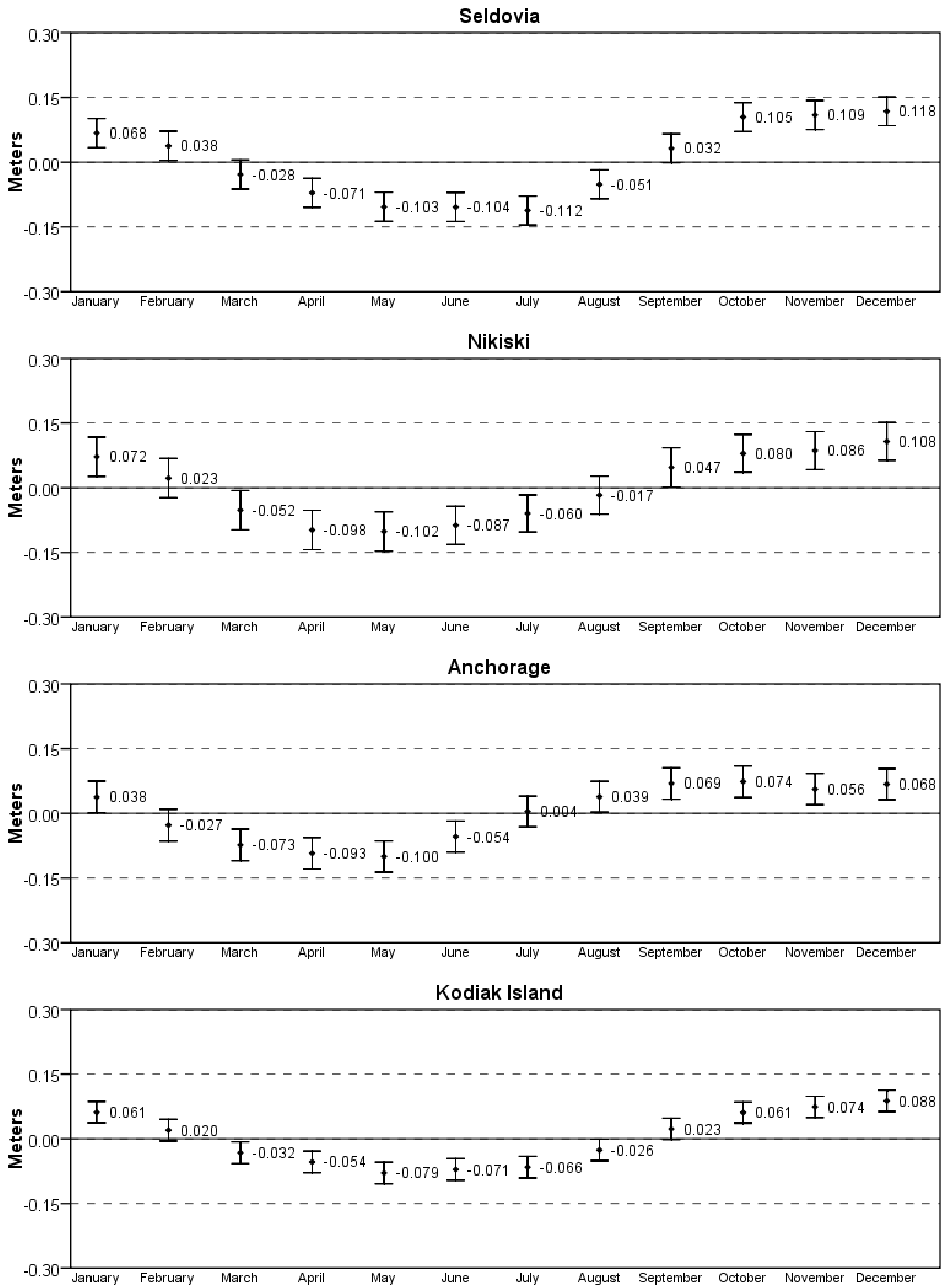
January February March April May June July August September October November December


Seldovia
Meters
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0.15
0.00
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-0.071
-0.103
-0.104
-0.112
-0.051
0.032
0.105
0.109
0.118
January
February
March
April
May
June
July
August
September
October
November
December
Nikiski
0.072
0.023
-0.052
-0.098
-0.102
-0.087
-0.060
-0.017
0.047
0.080
0.086
0.108
Anchorage
0.038
-0.027
-0.073
-0.093
-0.100
-0.054
0.004
0.039
0.069
0.074
0.056
0.068
Kodiak Island
0.061
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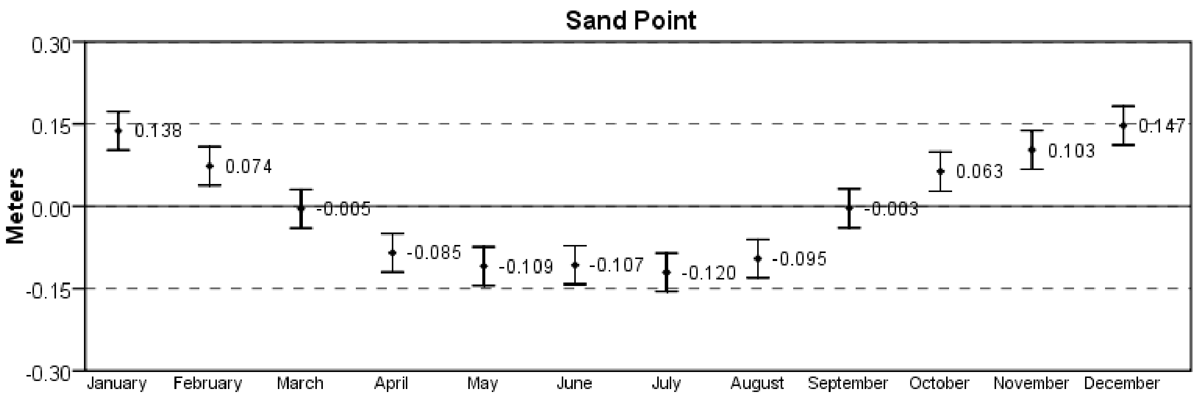
Sand Point
Meters
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-0.15
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0.138
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-0.120
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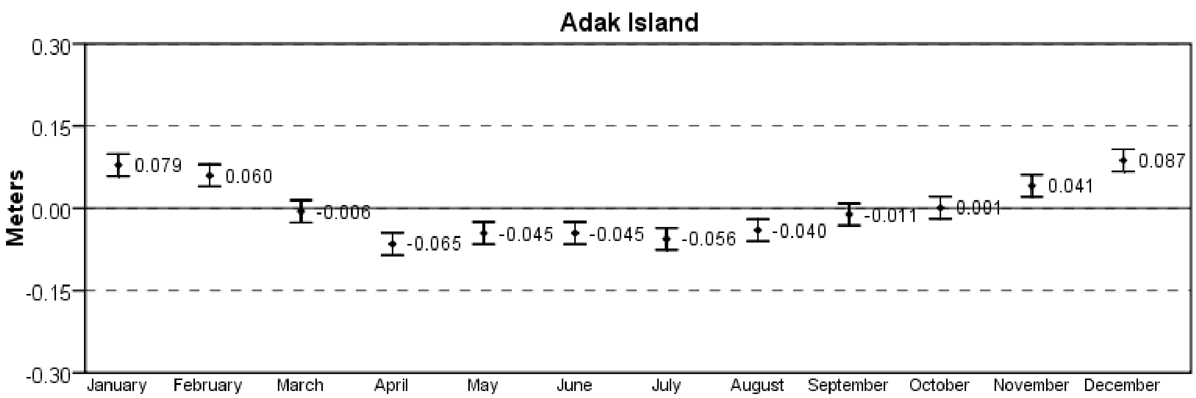
0.103
0.147
January February March April May June July August September October November December


Adak Island
Meters
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0.15
0.00
-0.15
-0.30
0.079
0.060
-0.006
-0.065
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-0.045
-0.056
-0.040
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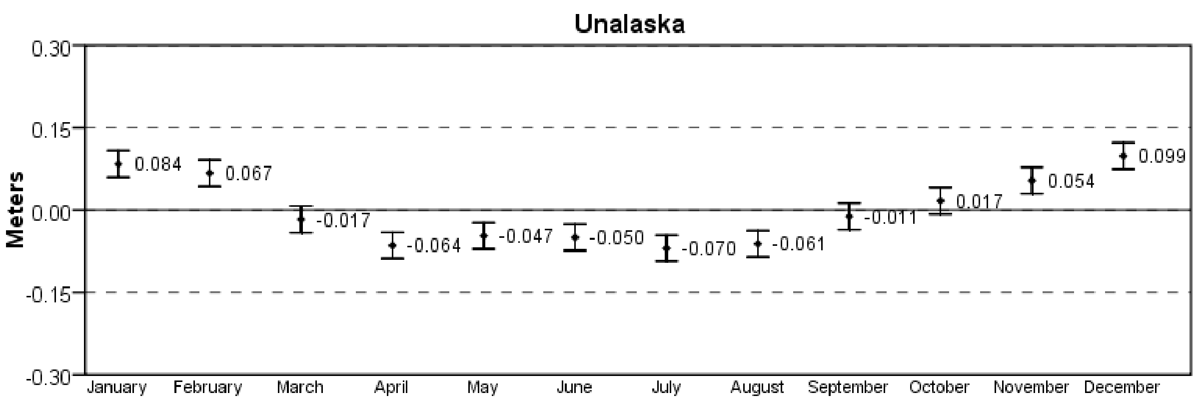
0.041
0.087
January February March April May June July August September October November December


Unalaska
Meters
0.30
0.15
0.00
-0.15
-0.30
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0.067
-0.017
-0.064
-0.047
-0.050
-0.070
-0.061
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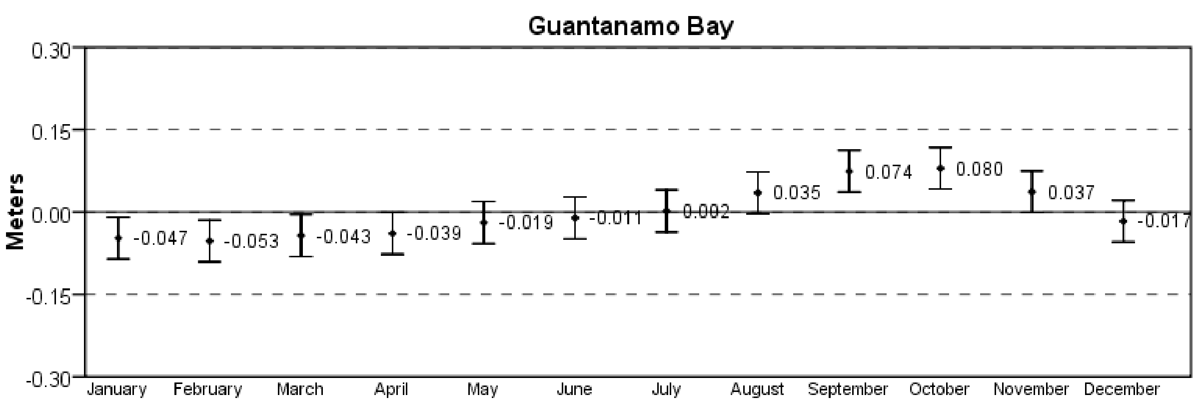
January February March April May June July August September October November December


Guantanamo Bay
Meters
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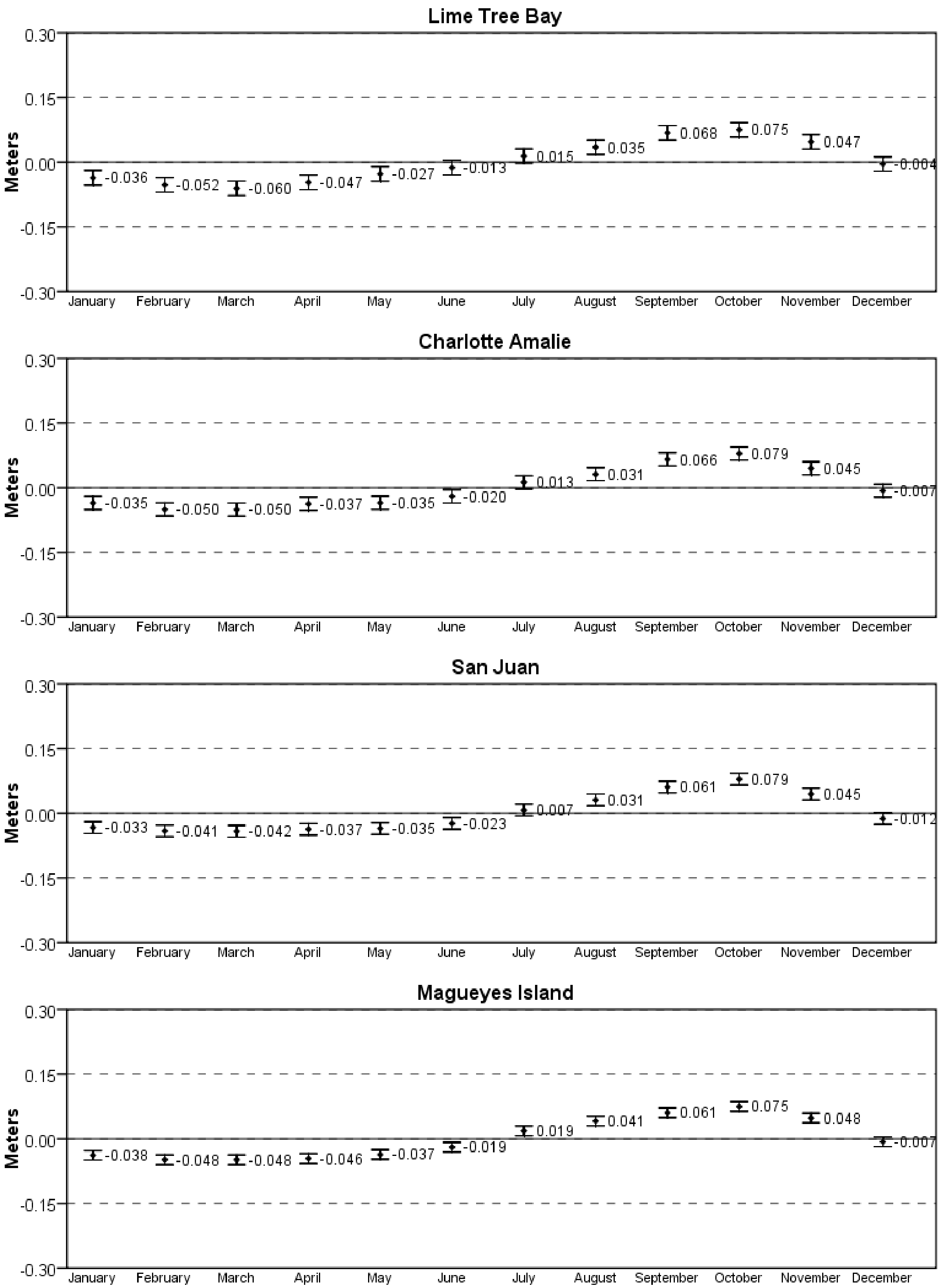
0.15
0.00
-0.15
-0.30
-0.047
-0.053
-0.043
-0.039
-0.019
-0.011
0.002
0.035
0.074
0.080
0.037
-0.017
January February March April May June July August September October November December


Lime Tree Bay
Meters
0.30
0.15
0.00
-0.15
-0.30
-0.036
-0.052
-0.060
-0.047
-0.027
-0.013
0.015
0.035
0.068
0.075
0.047
-0.004
January February March April May June July August September October November December
Charlotte Amalie
Meters
-0.035
-0.050
-0.050
-0.037
-0.035
-0.020
0.013
0.031
0.066
0.079
0.045
-0.007
San Juan
Meters
-0.033
-0.041
-0.042
-0.037
-0.035
-0.023
0.007
0.031
0.061
0.079
0.045
-0.012
Magueyes Island
Meters
-0.038
-0.048
-0.048
-0.046
-0.037
-0.019
0.019
0.041
0.061
0.075
0.048
-0.007

APPENDIX IV

Comparison of Sa and Ssa tidal constituents derived from average seasonal cycles with the accepted tidal constituents used for CO-OPS tide predictions

Station Number	Station Name	Derived tidal constituents from average seasonal cycles				Accepted tidal constituents used for official predictions			
		Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase	Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase
1611400	Nawiliwili	0.046	199.5	0.011	329.3	0.042	193.1	0	0
1612340	Honolulu	0.040	194.4	0.010	343.1	0.04	191.5	0	0
1612480	Mokuoloe	0.042	200.3	0.010	334.5	0	0	0	0
1615680	Kahului	0.041	195.7	0.014	333.7	0.038	199.5	0	0
1617760	Hilo	0.044	199.0	0.014	339.6	0.043	208.2	0	0
1619000	Johnston Atoll	0.063	209.8	0.012	312.4	0.054	204.3	0	0
1619910	Midway Atoll	0.049	231.4	0.021	287.4	0.039	232.5	0.035	287.8
1630000	Guam	0.065	97.4	0.011	320.0	0	0	0	0
1770000	Pago Pago	0.008	138.0	0.003	5.4	0	0	0	0
1820000	Kwajalein	0.033	80.1	0.023	25.4	0	0	0	0
1840000	Chuuk	0.031	62.2	0.029	36.2	0.033	62.6	0.032	25.7
1890000	Wake Island	0.040	177.0	0.014	329.4	0.056	165.5	0	0
2695540	Bermuda	0.069	187.8	0.013	23.1	0.062	180.2	0.012	83.1
8410410	Eastport	0.002	147.4	0.012	125.0	0	0	0.016	127.6
8413320	Bar Harbor	0.016	130.5	0.011	117.5	0	0	0	0
8418150	Portland	0.029	124.0	0.014	99.7	0.032	128.3	0.02	105.8
8419870	Seavey Island	0.024	106.5	0.015	84.8	0.033	125	0.016	101
8443970	Boston	0.029	133.0	0.015	87.4	0.032	126.3	0.018	89.8
8447930	Woods Hole	0.050	150.7	0.012	77.4	0.051	145.9	0	0
8449130	Nantucket Island	0.034	169.1	0.010	96.4	0.037	165.7	0	0
8452660	Newport	0.053	147.2	0.012	64.4	0.051	108.8	0.02	61.9
8454000	Providence	0.058	135.3	0.014	69.7	0.06	131.8	0	0
8461490	New London	0.053	136.7	0.018	61.0	0.055	135.3	0.018	69.4
8467150	Bridgeport	0.065	133.8	0.022	55.5	0.063	132	0.022	61.2
8510560	Montauk	0.049	146.0	0.015	54.3	0.069	135.1	0.034	50.9
8514560	Port Jefferson	0.059	137.5	0.022	43.5				
8516945	Kings Point	0.068	133.5	0.024	48.3	0.065	135.5	0.024	60.1
8518750	The Battery	0.073	131.0	0.026	57.3	0.07	129.9	0.03	47.4
8531680	Sandy Hook	0.069	133.5	0.028	48.6	0.067	129.1	0.028	42.9
8534720	Atlantic City	0.068	146.1	0.026	36.4	0.071	145.5	0.03	40
8536110	Cape May	0.061	146.5	0.029	40.6	0.058	147.7	0.032	40.3
8545240	Philadelphia	0.085	111.6	0.040	49.7	0.15	119.2	0.091	63
8551910	Reedy Point	0.099	124.3	0.039	41.7	0.096	120.1	0.037	43.6
8557380	Lewes	0.060	145.5	0.031	41.1	0.052	140.5	0.031	41.3
8570283	Ocean City	0.062	144.9	0.027	33.9	0	0	0	0
8571892	Cambridge	0.088	135.1	0.030	43.7	0.086	133.4	0.033	40.2
8573927	Chesapeake City	0.098	127.6	0.028	48.4	0.108	127.9	0.032	53.2
8574680	Baltimore	0.117	128.6	0.030	48.3	0.108	127.9	0.032	53.2
8575512	Annapolis	0.105	129.7	0.032	44.9	0.103	128.4	0.036	44.5
8577330	Solomons Island	0.092	133.7	0.035	39.9	0.087	131.4	0.034	36.1
8594900	Washington	0.087	117.4	0.040	34.8	0.077	110.6	0.038	40
8635150	Colonial Beach	0.095	127.9	0.034	34.6	0.086	124.3	0.018	18.4
8635750	Lewisetta	0.086	134.6	0.034	35.5	0.081	133.1	0.038	35.7
8632200	Kiptopeke	0.063	154.1	0.038	36.7	0.058	150.6	0.039	37.6
8637624	Gloucester Point	0.067	145.2	0.043	36.3	0.063	147	0.039	43.6
8638610	Sewells Point	0.062	152.4	0.043	35.5	0.048	149.2	0.037	33.9
8638660	Portsmouth	0.059	161.6	0.044	36.2	0.059	161.9	0.044	41.6

Table C. Comparison of long-term tidal constituent amplitudes and phases (meters, degrees)

Table C. Comparison of long-term tidal constituent amplitudes and phases (meters, degrees)									
Station Number	Station Name	Derived tidal constituents from average seasonal cycles				Accepted tidal constituents used for official predictions			
		Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase	Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase
8638863	Ches Bay Bridge Tunnel	0.058	152.7	0.041	34.5	0.055	152	0.042	34
8652587	Oregon Inlet Marina	0.062	154.2	0.026	45.0	0.046	158.9	0.026	10.5
8656483	Beaufort	0.071	165.8	0.041	46.4	0.066	166	0.036	57.1
8658120	Wilmington	0.044	151.1	0.038	25.7	0	0	0.051	24.9
8659084	Southport	0.070	167.6	0.042	57.2	0	0	0	0
8661070	Springmaid Pier	0.094	168.3	0.053	53.9	0.083	170.9	0.053	50.1
8665530	Charleston	0.084	172.3	0.057	51.9	0.078	176.3	0.053	50.5
8670870	Fort Pulaski	0.093	172.7	0.066	52.9	0.084	176	0.06	51.8
8720030	Fernandina Beach	0.098	186.2	0.079	55.0	0.086	119.6	0.07	54.7
8720218	Mayport	0.105	192.9	0.073	53.9	0.115	190.2	0.077	55.4
8721120	Daytona Beach Shores	0.097	200.2	0.065	62.3	0.104	197.5	0.077	52.4
8723170	Miami Beach	0.084	196.5	0.053	66.5	0.088	198.8	0.062	68.7
8723970	Vaca Key	0.079	190.2	0.038	59.0	0.083	196.1	0.033	70.5
8724580	Key West	0.080	182.6	0.039	58.4	0.08	187.8	0.041	56.5
8725110	Naples	0.083	159.4	0.032	47.8	0.075	167.9	0.03	66.7
8725520	Fort Myers	0.092	146.6	0.024	32.1	0.082	150.7	0	0
8726520	St. Petersburg	0.090	149.0	0.025	44.6	0.092	150.8	0.033	41
8726724	Clearwater Beach	0.089	149.3	0.032	49.3	0.091	151.9	0.037	48.2
8727520	Cedar Key	0.102	138.6	0.024	41.9	0.096	136.4	0	0
8728690	Apalachicola	0.078	139.9	0.041	24.9	0.075	145.1	0.036	28.7
8729108	Panama City	0.098	148.1	0.040	41.4	0.095	150.6	0.034	48.9
8729840	Pensacola	0.091	146.6	0.043	37.8	0.087	148.3	0.048	43.2
8735180	Dauphin Island	0.079	147.8	0.050	44.2	0.08	156.3	0.05	51.3
8761724	Grand Isle	0.080	148.9	0.053	42.9	0.087	149.7	0.06	49.7
8764311	Eugene Island	0.079	126.1	0.057	47.3	0	0	0	0
8770570	Sabine Pass	0.065	141.5	0.071	51.5	0.065	135.7	0.077	52
8771450	Galveston Pier 21	0.069	150.7	0.076	54.3	0.066	155.7	0.086	55.6
8771510	Galveston Pleasure Pier	0.077	153.9	0.081	52.1	0.077	157.4	0.09	55.2
8772440	Freeport	0.070	161.9	0.081	54.1	0.057	173.5	0.074	64.3
8774770	Rockport	0.063	151.0	0.085	59.7	0.061	161	0.09	69.9
8778490	Port Mansfield	0.055	147.5	0.093	64.9				
8779750	Padre Island	0.063	199.1	0.072	57.3	0.081	206.6	0.085	56.2
8779770	Port Isabel	0.058	193.9	0.074	52.5	0.055	196.1	0.069	58.8
9410170	San Diego	0.067	183.1	0.015	269.7	0.069	179.3	0	0
9410230	La Jolla	0.069	182.6	0.015	271.8	0.07	184.3	0.017	263.2
9410580	Newport Beach	0.063	184.1	0.017	278.5	0.063	183.4	0.014	280.2
9410660	Los Angeles	0.064	184.4	0.016	268.9	0.066	184.4	0	0
9410840	Santa Monica	0.063	180.8	0.019	279.3	0.065	183.2	0	0
9411270	Rincon Island	0.062	186.2	0.015	271.1				
9411340	Santa Barbara	0.059	191.0	0.017	272.5	0.079	156.8	0	0
9412110	Port San Luis	0.059	194.9	0.020	265.7	0.056	191.9	0.032	279.1
9413450	Monterey	0.050	204.8	0.023	282.2	0.048	206	0.027	283.9
9414290	San Francisco	0.032	212.7	0.027	270.1	0.038	221.4	0.039	286.9
9414523	Redwood City	0.030	220.0	0.029	274.0	0.038	221.4	0.039	286.9
9414750	Alameda	0.022	198.6	0.021	261.6	0.032	227.8	0.037	288.3
9415144	Port Chicago	0.005	146.2	0.048	278.6	0	0	0.06	285.7
9415020	Point Reyes	0.055	220.7	0.034	277.0	0.061	217.7	0.031	285.3
9418767	North Spit	0.069	257.5	0.035	269.8	0.065	255	0.038	264.1

Table C. Comparison of long-term tidal constituent amplitudes and phases (meters, degrees)									
Station Number	Station Name	Derived tidal constituents from average seasonal cycles				Accepted tidal constituents used for official predictions			
		Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase	Sa Ampl.	Sa Phase	Ssa Ampl.	Ssa Phase
9419750	Crescent City	0.075	260.7	0.034	257.2	0.071	261.4	0.041	262.1
9431647	Port Orford	0.102	273.5	0.033	271.9	0.093	268	0	0
9432780	Charleston	0.104	280.5	0.025	250.8	0.103	283.3	0	0
9435380	South Beach	0.124	285.2	0.025	247.0	0.123	281.6	0.019	258.7
9437540	Garibaldi	0.150	287.4	0.022	216.5	0	0	0	0
9439040	Astoria	0.101	314.2	0.048	178.3	0.111	307.2	0.052	184.1
9440910	Toke Point	0.167	290.2	0.018	201.6	0.158	289.8	0	0
9443090	Neah Bay	0.130	285.0	0.018	210.6	0.126	289.9	0	0
9444090	Port Angeles	0.100	287.4	0.020	236.5	0.101	287.6	0	0
9444900	Port Townsend	0.087	290.7	0.024	236.0	0.082	292	0	0
9447130	Seattle	0.076	289.8	0.027	222.3	0.077	292.9	0.033	231.1
9449424	Cherry Point	0.065	277.1	0.029	238.5	0.05	280.1	0.023	236.5
9449880	Friday Harbor	0.076	281.5	0.028	228.1	0.085	280.4	0.039	221
9450460	Ketchikan	0.108	266.4	0.026	146.6	0.115	273.7	0.031	161.1
9451600	Sitka	0.119	267.6	0.018	125.9	0.121	274.8	0	0
9452210	Juneau	0.082	235.8	0.021	145.1	0.08	255.6	0	0
9452400	Skagway	0.086	194.2	0.015	168.7	0.059	190	0	0
9453220	Yakutat	0.122	255.6	0.016	100.9	0.122	265.1	0.033	59.8
9454050	Cordova	0.123	248.1	0.010	56.1	0.131	254.2	0	0
9454240	Valdez	0.108	239.6	0.002	128.5	0.112	243.1	0	0
9455090	Seward	0.125	245.5	0.012	80.7	0.118	253.3	0	0
9455500	Seldovia	0.119	251.6	0.014	67.0	0.116	251.4	0.017	70.8
9455760	Nikiski	0.105	240.7	0.009	221.1	0.12	243.7	0	0
9455920	Anchorage	0.088	213.6	0.017	245.0	0.054	230.2	0.072	45.6
9457292	Kodiak Island	0.083	249.1	0.004	143.4	0.078	262.1	0.015	151.7
9459450	Sand Point	0.137	266.7	0.014	182.2	0.123	272.3	0	0
9462620	Unalaska	0.080	271.4	0.020	193.4	0.094	277.7	0.039	216.2
9461380	Adak Island	0.068	272.1	0.022	214.5	0.076	269.4	0.021	206.2
9731158	Guantanamo Bay	0.058	176.9	0.023	40.2				
9751401	Lime Tree Bay	0.062	181.0	0.013	57.4	0.059	184.9	0.015	60
9751639	Charlotte Amalie	0.059	183.4	0.017	43.0	0.061	181.8	0.019	47.2
9755371	San Juan	0.055	185.9	0.018	32.3	0.055	186.9	0.021	37.1
9759110	Magueyes Island	0.061	182.3	0.013	37.8	0.062	184.2	0.016	42.6

Appendix V

Linear trends for 50-year periods of mean sea level data

Note Derived 50-year linear trends and 95% confidence intervals of the trends are shown for stations with over 80 years of data. Solid horizontal line shows linear trend derived from station's entire data set.

Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
1612340	Honolulu	1902	1951	1927	2.03	0.84
		1907	1956	1932	1.67	0.78
		1912	1961	1937	1.36	0.73
		1917	1966	1942	1.44	0.67
		1922	1971	1947	1.48	0.61
		1927	1976	1952	1.45	0.64
		1932	1981	1957	1.50	0.61
		1937	1986	1962	1.13	0.66
		1942	1991	1967	0.95	0.68
		1947	1996	1972	1.56	0.67
		1952	2001	1977	1.30	0.69
		1957	2006	1982	1.29	0.67
1617760	Hilo	1927	1976	1952	3.20	0.68
		1947	1996	1972	3.63	0.60
		1952	2001	1977	2.93	0.65
		1957	2006	1982	2.75	0.65
8418150	Portland	1912	1961	1937	2.38	0.39
		1917	1966	1942	2.24	0.39
		1922	1971	1947	3.02	0.39
		1927	1976	1952	2.82	0.41
		1932	1981	1957	2.61	0.41
		1937	1986	1962	2.14	0.42
		1942	1991	1967	1.49	0.43
		1947	1996	1972	1.13	0.43
		1952	2001	1977	1.01	0.42
		1957	2006	1982	1.20	0.46
8443970	Boston	1922	1971	1947	3.50	0.36
		1927	1976	1952	3.17	0.37
		1932	1981	1957	2.48	0.38
		1937	1986	1962	2.10	0.36
		1942	1991	1967	1.68	0.37
		1947	1996	1972	1.79	0.38
		1952	2001	1977	1.96	0.39
		1957	2006	1982	2.25	0.43
8518750	The Battery	1857	1906	1882	2.51	0.52
		1862	1911	1887	2.71	0.45
		1867	1916	1892	2.41	0.45
		1872	1921	1897	2.91	0.48
		1892	1941	1917	2.23	0.40
		1897	1946	1922	2.57	0.39
		1902	1951	1927	3.03	0.39
		1907	1956	1932	3.45	0.37
		1912	1961	1937	3.59	0.38
		1917	1966	1942	3.36	0.38

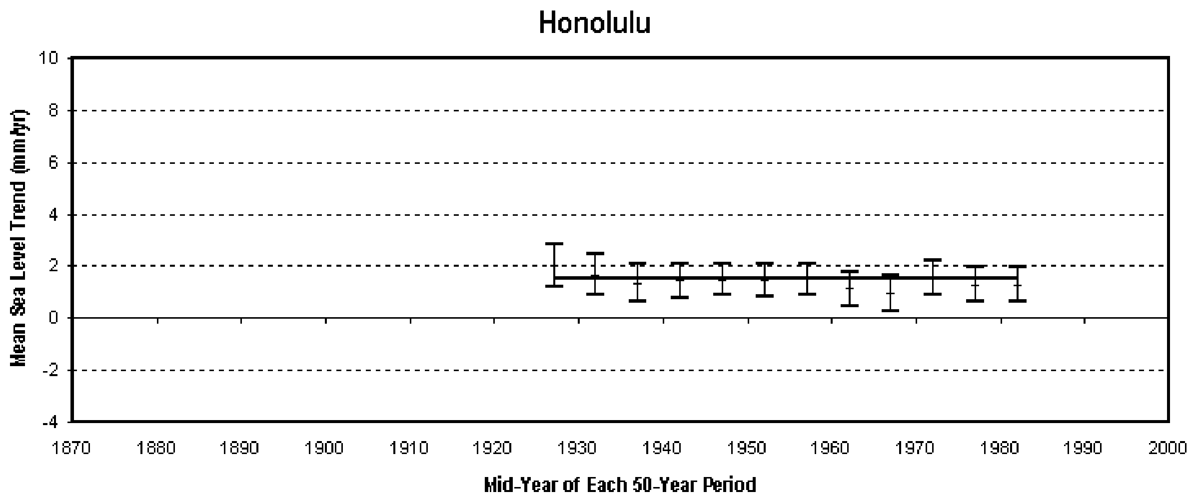
Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
		1922	1971	1947	3.76	0.36
		1927	1976	1952	3.55	0.40
		1932	1981	1957	2.81	0.43
		1937	1986	1962	2.51	0.43
		1942	1991	1967	2.19	0.44
		1947	1996	1972	2.41	0.46
		1952	2001	1977	2.63	0.47
		1957	2006	1982	2.83	0.50
8534720	Atlantic City	1912	1961	1937	3.90	0.41
		1917	1966	1942	3.67	0.42
		1922	1971	1947	4.10	0.43
		1927	1976	1952	4.04	0.44
		1932	1981	1957	3.26	0.44
		1937	1986	1962	3.44	0.46
		1942	1991	1967	3.56	0.48
		1947	1996	1972	4.05	0.51
		1952	2001	1977	4.36	0.52
		1957	2006	1982	4.47	0.55
8545240	Philadelphia	1902	1951	1927	2.73	0.61
		1907	1956	1932	3.49	0.58
		1912	1961	1937	3.48	0.61
		1917	1966	1942	2.58	0.65
		1922	1971	1947	2.88	0.63
		1927	1976	1952	2.80	0.65
		1932	1981	1957	2.05	0.64
		1937	1986	1962	2.10	0.65
		1942	1991	1967	2.08	0.63
		1947	1996	1972	2.44	0.67
		1952	2001	1977	2.61	0.68
		1957	2006	1982	3.44	0.70
8557730	Lewes	1917	1966	1942	3.17	0.54
		1937	1986	1962	3.04	0.61
		1947	1996	1972	2.62	0.54
		1952	2001	1977	2.98	0.53
		1957	2006	1982	3.29	0.54
8574680	Baltimore	1902	1951	1927	3.20	0.42
		1907	1956	1932	3.73	0.38
		1912	1961	1937	4.02	0.39
		1917	1966	1942	3.67	0.40
		1922	1971	1947	3.91	0.40
		1927	1976	1952	3.77	0.41
		1932	1981	1957	2.75	0.46
		1937	1986	1962	2.50	0.44
		1942	1991	1967	2.17	0.44
		1947	1996	1972	2.40	0.44
		1952	2001	1977	2.61	0.47

Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
		1957	2006	1982	2.90	0.48
8594900	Washington	1922	1971	1947	3.49	0.65
		1932	1981	1957	2.73	0.61
		1937	1986	1962	2.67	0.60
		1942	1991	1967	2.34	0.61
		1947	1996	1972	2.81	0.66
		1952	2001	1977	2.93	0.70
		1957	2006	1982	3.16	0.75
8638610	Sewells Point	1927	1976	1952	4.55	0.48
		1932	1981	1957	3.78	0.49
		1937	1986	1962	3.84	0.50
		1942	1991	1967	3.70	0.53
		1947	1996	1972	3.96	0.55
		1952	2001	1977	4.39	0.58
		1957	2006	1982	4.70	0.61
8665530	Charleston	1922	1971	1947	3.56	0.53
		1927	1976	1952	3.78	0.55
		1932	1981	1957	2.86	0.55
		1937	1986	1962	2.75	0.56
		1942	1991	1967	2.19	0.55
		1947	1996	1972	2.40	0.56
		1952	2001	1977	3.06	0.52
		1957	2006	1982	2.90	0.54
8720030	Fernandina Beach	1897	1946	1922	1.24	0.72
		1902	1951	1927	2.07	0.73
		1907	1956	1932	2.56	0.66
		1912	1961	1937	2.72	0.61
		1917	1966	1942	2.53	0.66
		1922	1971	1947	2.29	0.75
		1937	1986	1962	1.91	0.62
		1942	1991	1967	1.77	0.61
		1947	1996	1972	2.06	0.65
		1952	2001	1977	2.55	0.60
		1957	2006	1982	2.37	0.61
8724580	Key West	1912	1961	1937	2.62	0.42
		1917	1966	1942	2.42	0.43
		1922	1971	1947	2.31	0.44
		1927	1976	1952	2.25	0.45
		1932	1981	1957	1.87	0.41
		1937	1986	1962	1.89	0.42
		1942	1991	1967	1.77	0.43
		1947	1996	1972	1.98	0.44
		1952	2001	1977	2.41	0.41
		1957	2006	1982	2.41	0.41
8727520	Cedar Key	1912	1961	1937	2.67	0.43
		1917	1966	1942	2.12	0.49

Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
		1922	1971	1947	1.81	0.60
		1937	1986	1962	1.29	0.50
		1942	1991	1967	1.10	0.47
		1947	1996	1972	1.29	0.49
		1952	2001	1977	1.74	0.46
		1957	2006	1982	1.64	0.46
8729840	Pensacola	1922	1971	1947	2.24	0.60
		1927	1976	1952	2.42	0.60
		1932	1981	1957	1.86	0.56
		1937	1986	1962	1.78	0.56
		1942	1991	1967	1.34	0.55
		1947	1996	1972	1.47	0.54
		1952	2001	1977	1.96	0.53
		1957	2006	1982	1.89	0.55
8771450	Galveston Pier 21	1907	1956	1932	5.94	0.86
		1912	1961	1937	6.25	0.80
		1917	1966	1942	6.11	0.83
		1922	1971	1947	6.12	0.75
		1927	1976	1952	6.64	0.80
		1932	1981	1957	6.64	0.76
		1937	1986	1962	6.74	0.77
		1942	1991	1967	6.52	0.74
		1947	1996	1972	6.86	0.74
		1952	2001	1977	7.27	0.70
		1957	2006	1982	6.61	0.73
9410170	San Diego	1907	1956	1932	1.82	0.42
		1912	1961	1937	2.17	0.46
		1917	1966	1942	2.22	0.45
		1922	1971	1947	1.98	0.45
		1927	1976	1952	1.88	0.48
		1932	1981	1957	1.95	0.48
		1937	1986	1962	2.31	0.60
		1942	1991	1967	2.33	0.58
		1947	1996	1972	2.43	0.61
		1952	2001	1977	2.06	0.74
		1957	2006	1982	1.83	0.72
9410230	La Jolla	1922	1971	1947	1.82	0.55
		1927	1976	1952	1.76	0.51
		1932	1981	1957	1.96	0.51
		1937	1986	1962	2.19	0.60
		1942	1991	1967	2.47	0.58
		1947	1996	1972	2.57	0.62
		1952	2001	1977	2.38	0.75
		1957	2006	1982	1.96	0.69
9410660	Los Angeles	1922	1971	1947	0.53	0.50
		1927	1976	1952	0.43	0.48

Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
		1932	1981	1957	0.48	0.48
		1937	1986	1962	0.54	0.54
		1942	1991	1967	0.57	0.52
		1947	1996	1972	1.07	0.56
		1952	2001	1977	0.97	0.66
		1957	2006	1982	0.94	0.64
9414290	San Francisco	1852	1901	1877	1.14	0.94
		1857	1906	1882	1.24	0.82
		1862	1911	1887	0.26	0.77
		1867	1916	1892	-0.24	0.68
		1872	1921	1897	-0.40	0.66
		1877	1926	1902	-0.67	0.63
		1882	1931	1907	-0.17	0.59
		1887	1936	1912	0.47	0.51
		1892	1941	1917	1.46	0.59
		1897	1946	1922	1.72	0.55
		1902	1951	1927	1.60	0.53
		1907	1956	1932	1.74	0.51
		1912	1961	1937	2.01	0.54
		1917	1966	1942	2.34	0.50
		1922	1971	1947	2.43	0.52
		1927	1976	1952	2.12	0.54
		1932	1981	1957	1.84	0.58
		1937	1986	1962	2.31	0.74
		1942	1991	1967	2.18	0.68
		1947	1996	1972	2.37	0.71
		1952	2001	1977	2.01	0.78
		1957	2006	1982	1.80	0.77
9439040	Astoria	1922	1971	1947	-0.10	0.81
		1927	1976	1952	-0.16	0.77
		1932	1981	1957	-0.76	0.79
		1937	1986	1962	-0.34	0.87
		1942	1991	1967	-0.89	0.86
		1947	1996	1972	-0.96	0.84
		1952	2001	1977	-0.30	0.87
		1957	2006	1982	-0.19	0.84
9447130	Seattle	1897	1946	1922	1.06	0.50
		1902	1951	1927	1.25	0.46
		1907	1956	1932	1.65	0.46
		1912	1961	1937	2.31	0.47
		1917	1966	1942	2.57	0.47
		1922	1971	1947	2.82	0.46
		1927	1976	1952	2.57	0.47
		1932	1981	1957	2.39	0.48
		1937	1986	1962	2.60	0.56
		1942	1991	1967	2.32	0.54

Table D. Linear trends for 50-year periods of MSL data						
Station Number	**Station**	**Beginning Year**	**Ending Year**	**Middle Year**	**MSL Trend (mm/yr)**	**+/- 95% Confidence Interval (mm/yr)**
		1947	1996	1972	2.26	0.56
		1952	2001	1977	2.09	0.62
		1957	2006	1982	1.95	0.60
9450460	Ketchikan	1917	1966	1942	-0.29	0.62
		1922	1971	1947	0.08	0.62
		1927	1976	1952	-0.33	0.62
		1932	1981	1957	-0.40	0.59
		1937	1986	1962	-0.10	0.64
		1942	1991	1967	0.06	0.61
		1947	1996	1972	-0.02	0.64
		1952	2001	1977	-0.27	0.68
		1957	2006	1982	-0.38	0.69
9451600	Sitka	1922	1971	1947	-2.15	0.75
		1937	1986	1962	-2.16	0.56
		1942	1991	1967	-2.00	0.53
		1947	1996	1972	-2.02	0.55
		1952	2001	1977	-2.09	0.59
		1957	2006	1982	-1.96	0.60


Honolulu
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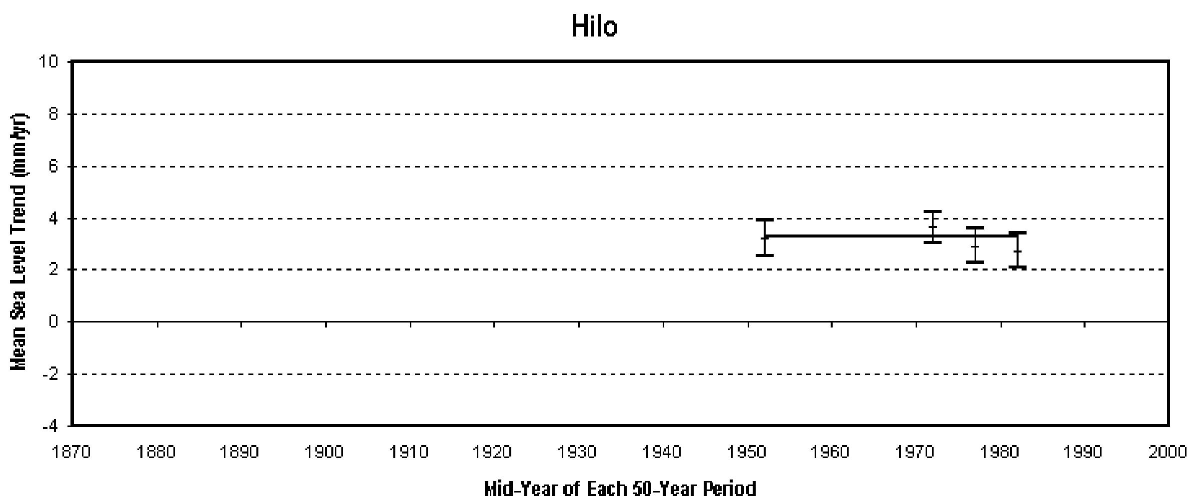
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Hilo
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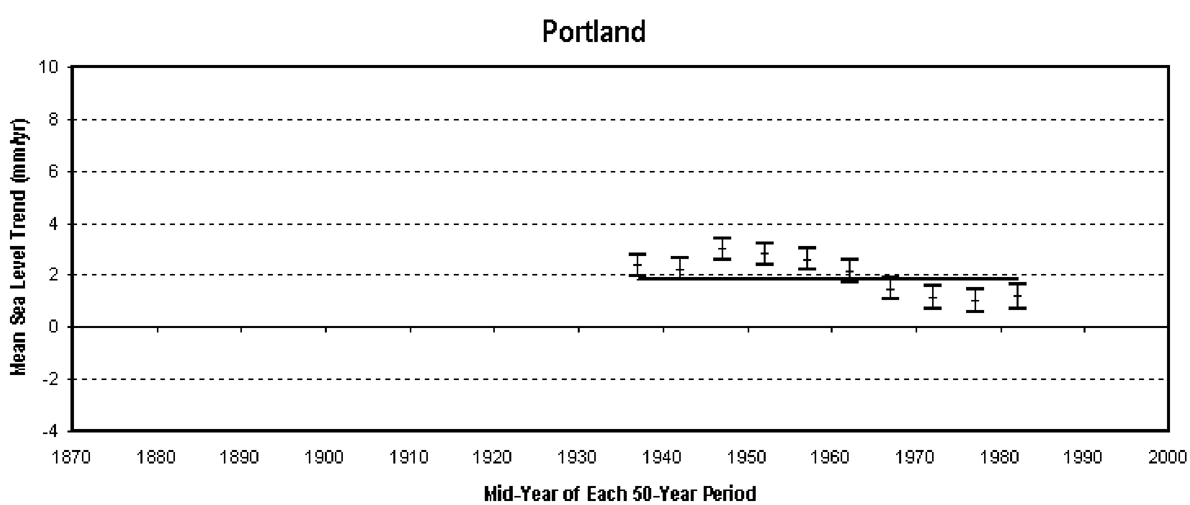
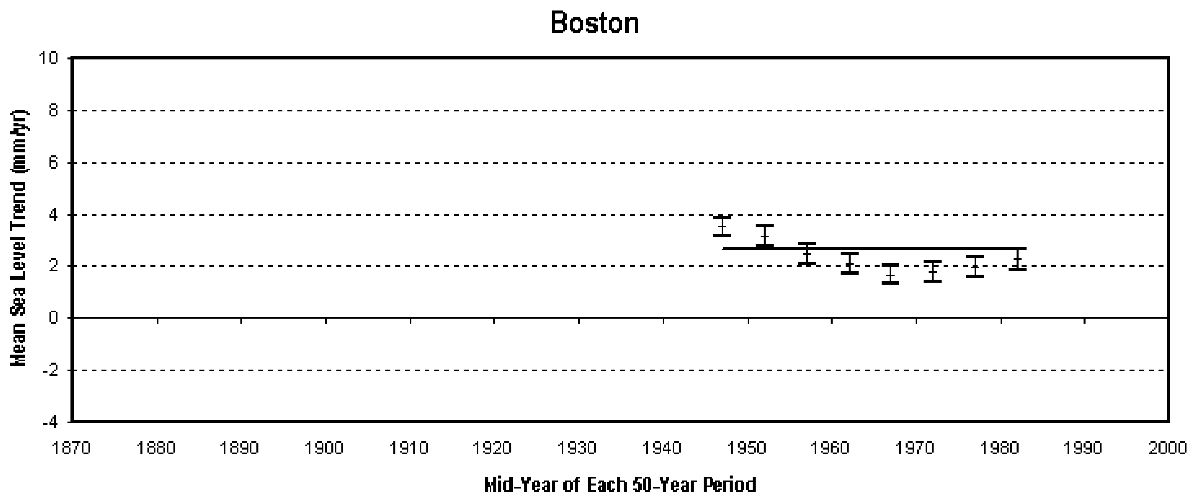
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Portland
10
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Boston
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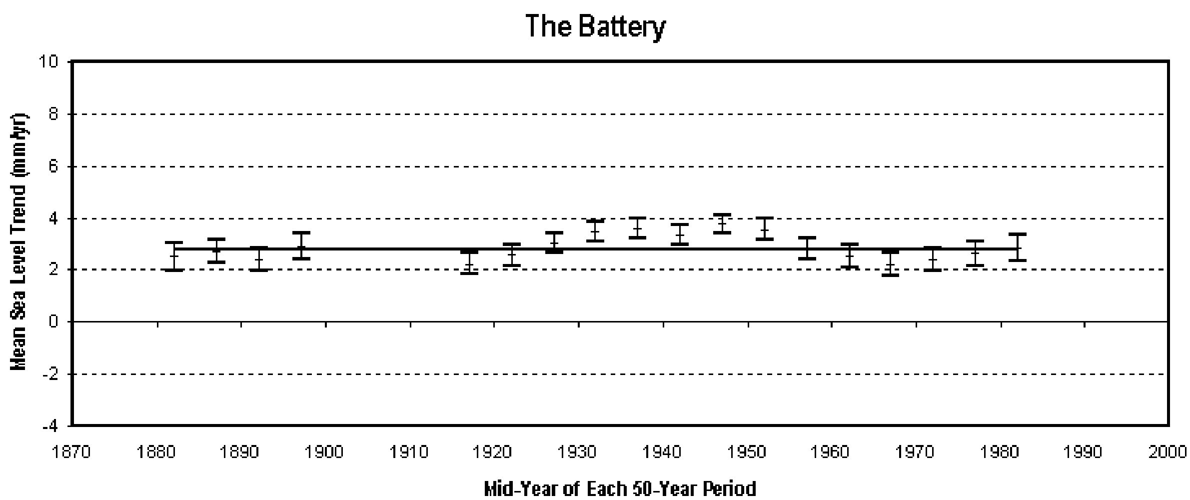
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mean Sea Level Trend (mm/yr)
Mid-Year of Each 50-Year Period


The Battery
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
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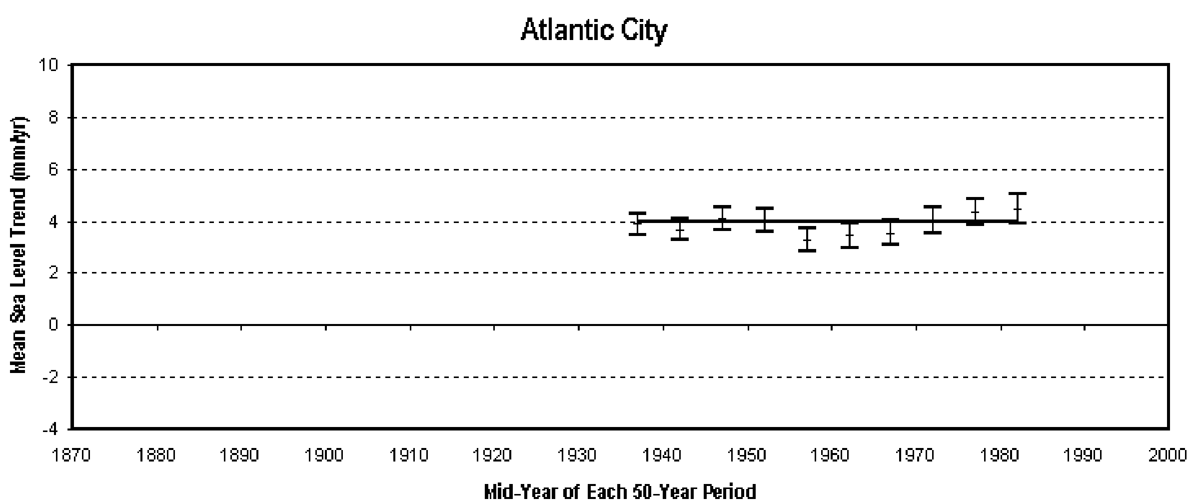
1950
1960
1970
1980
1990
2000
Mean Sea Level Trend (mm/yr)
Mid-Year of Each 50-Year Period


Atlantic City
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4
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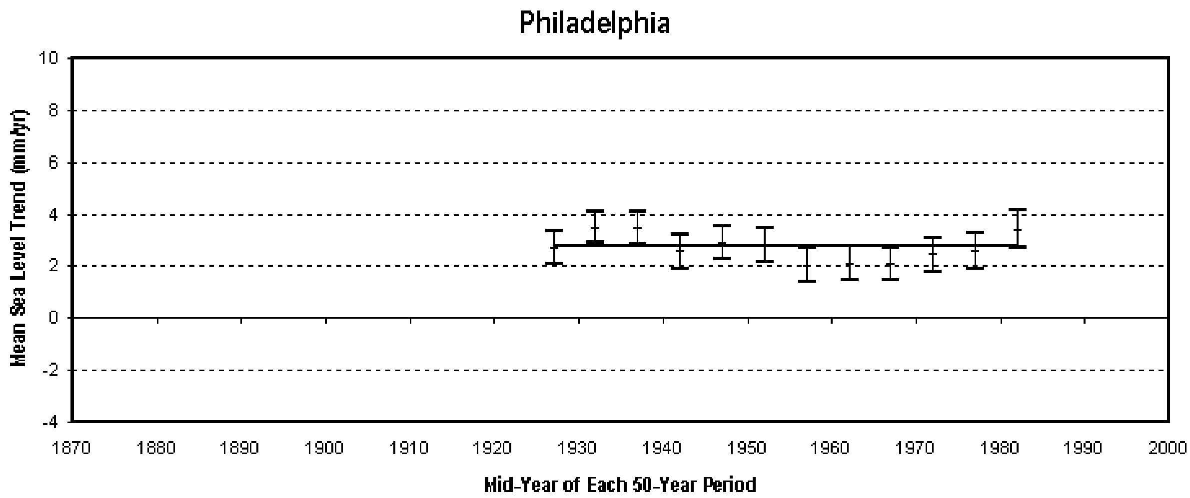
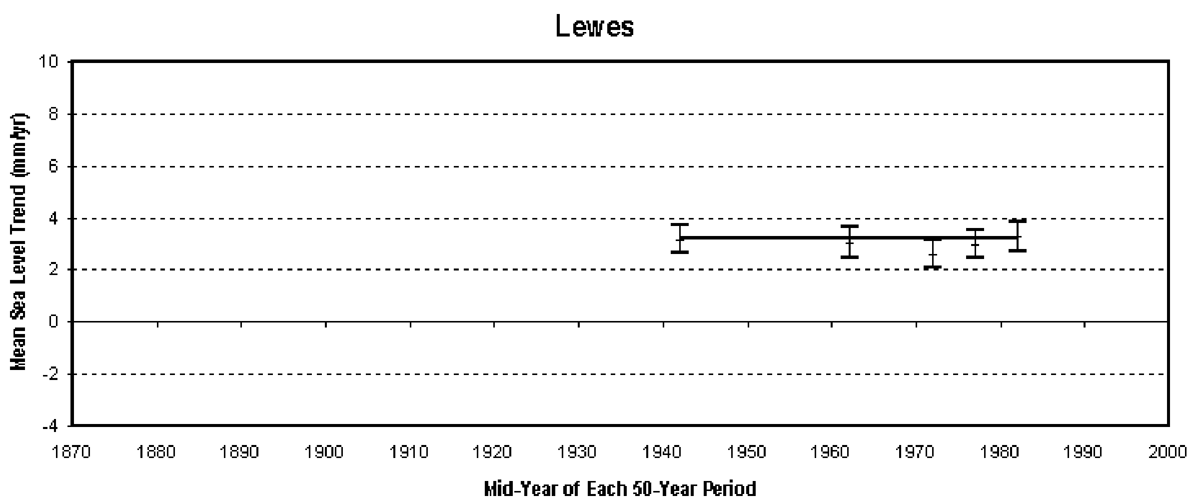
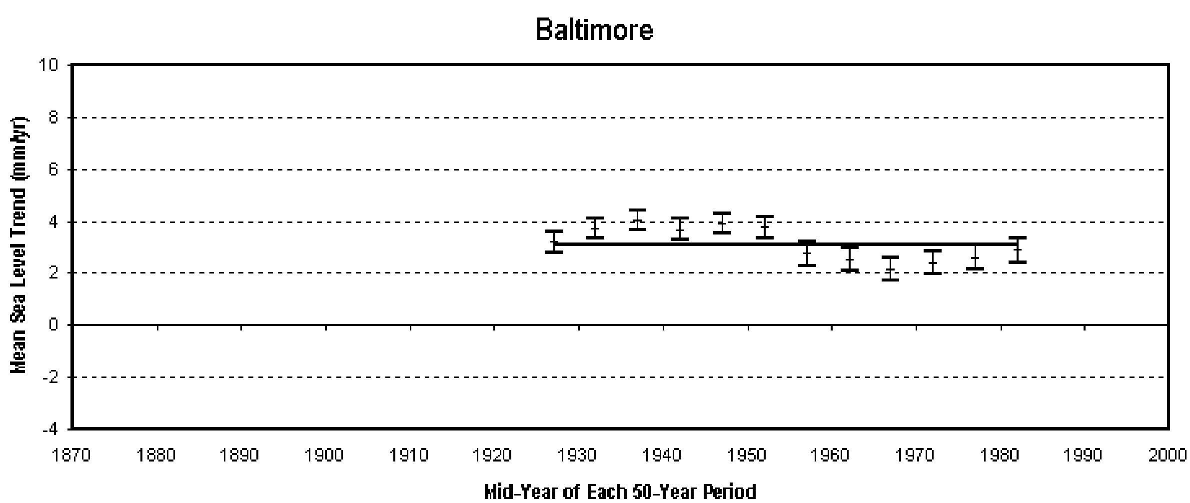
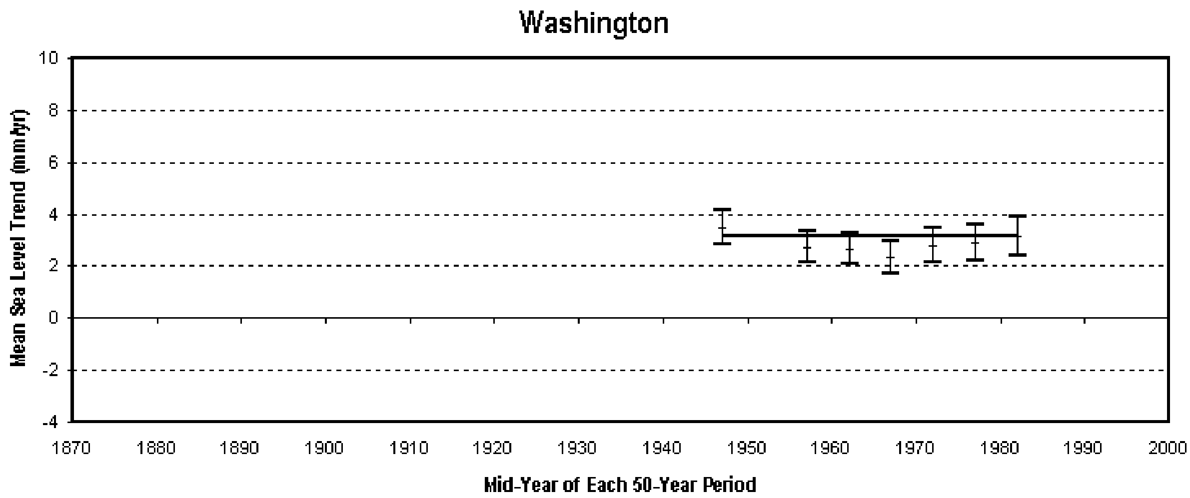
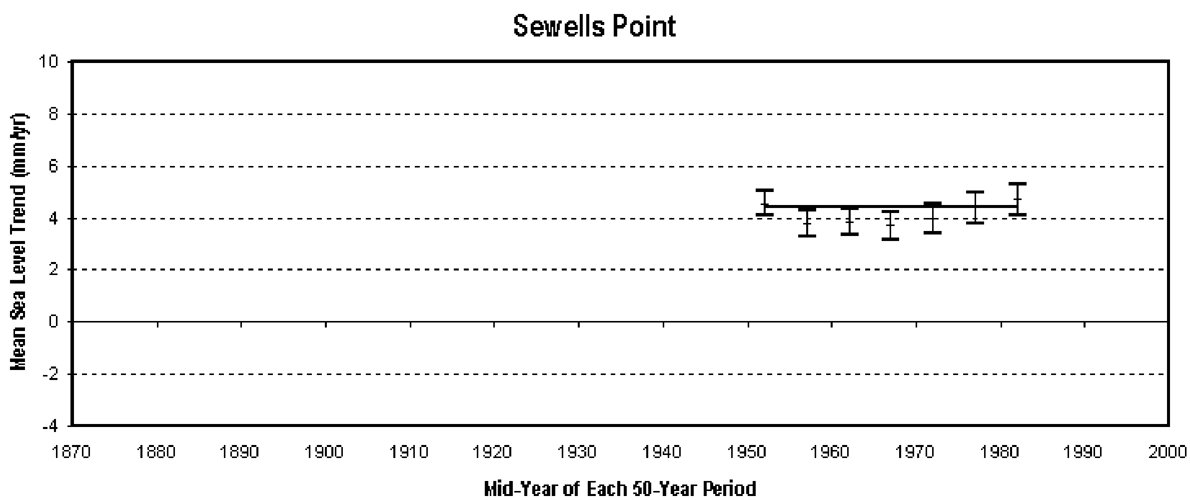
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mean Sea Level Trend (mm/yr)
Mid-Year of Each 50-Year Period

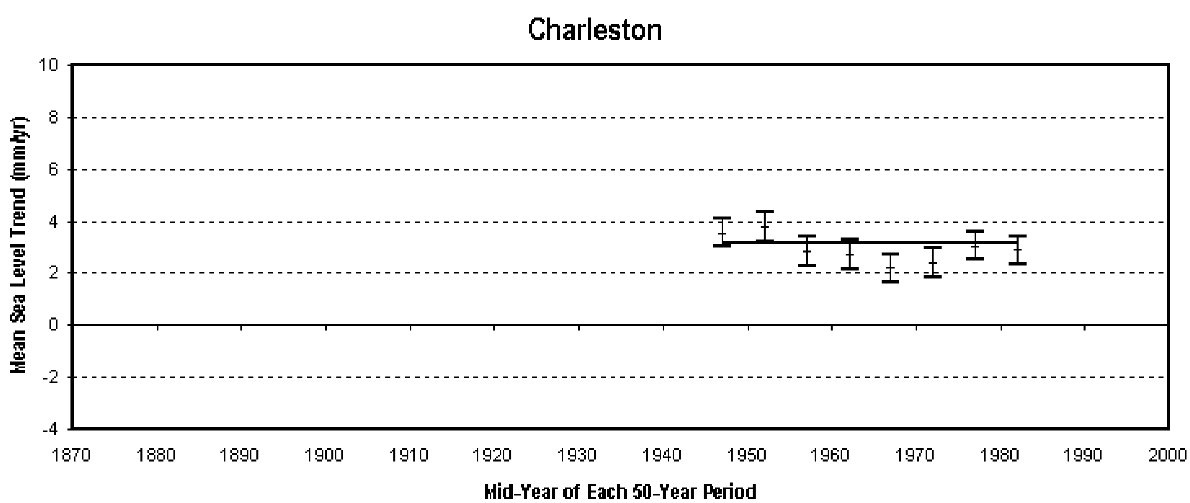

Philadelphia
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

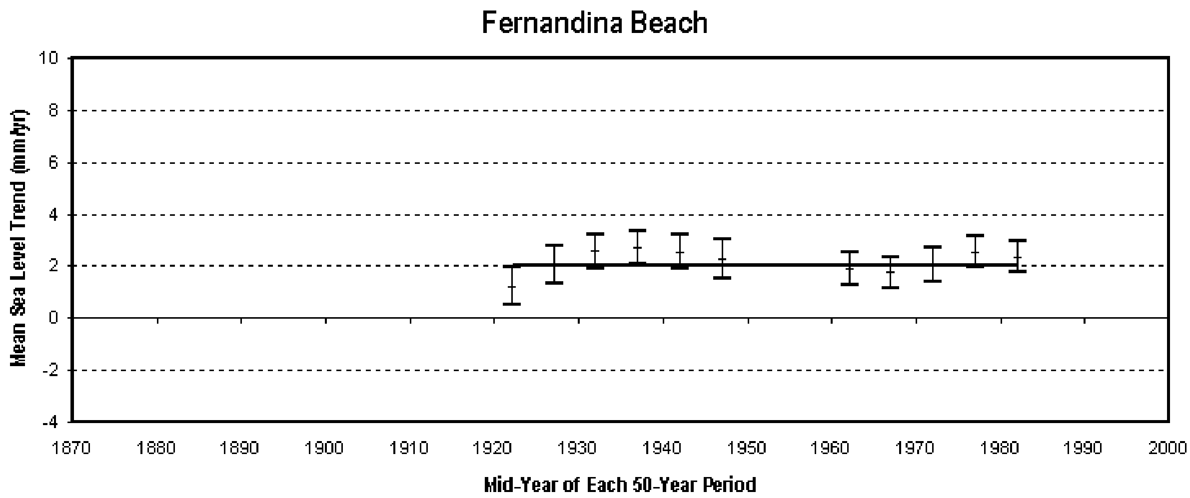

Lewes
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

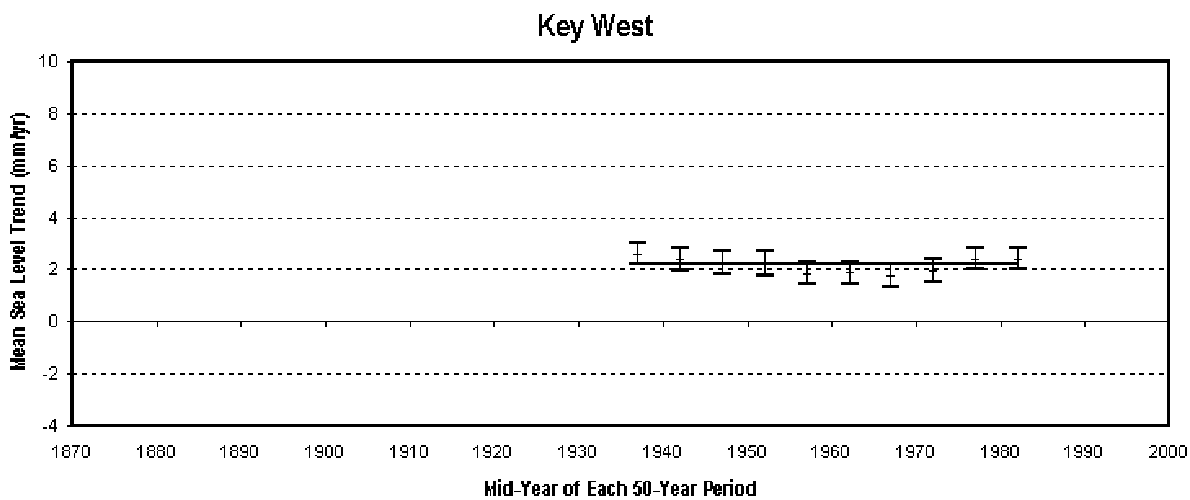

Baltimore
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

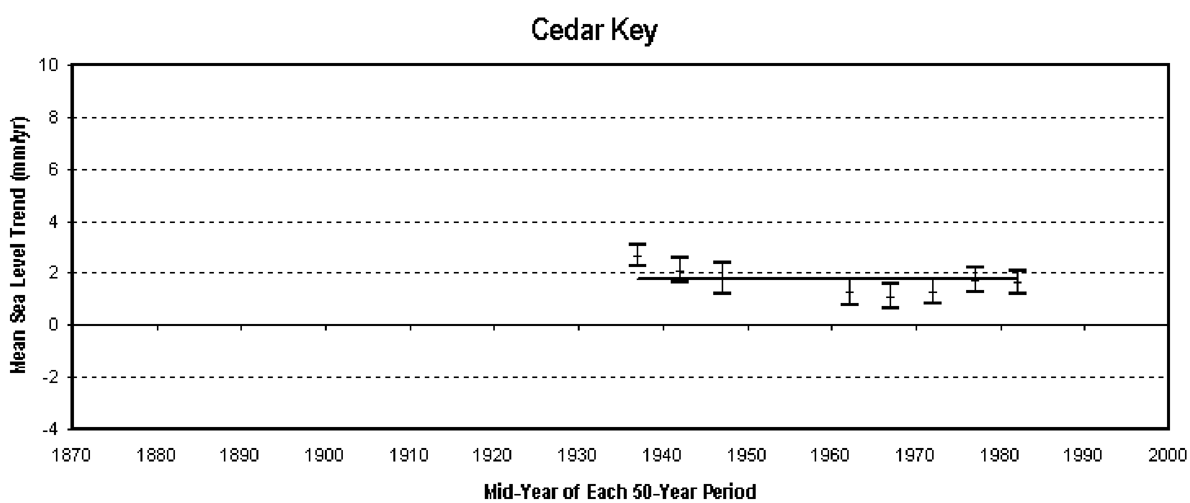

Washington
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

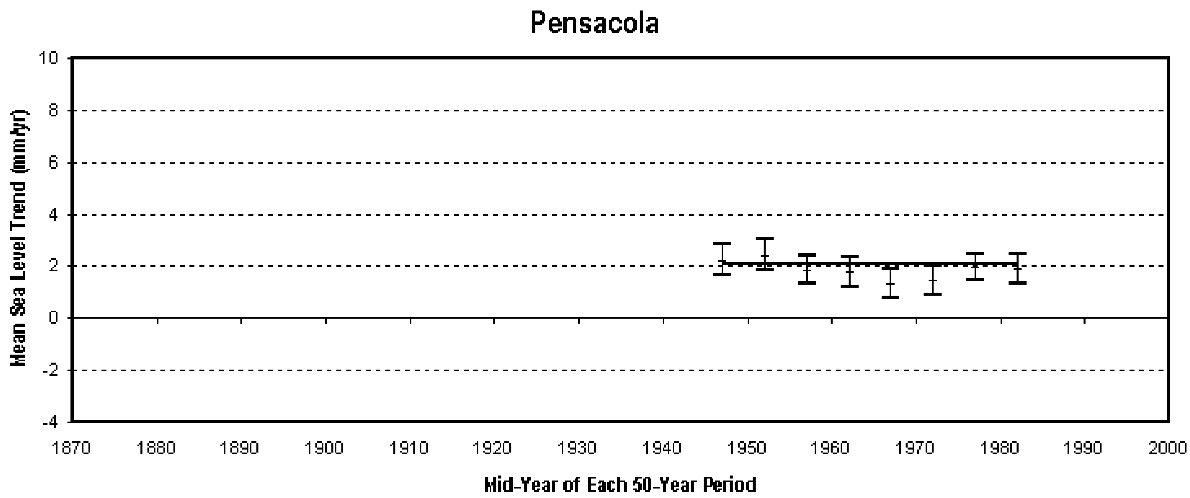

Sewells Point
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

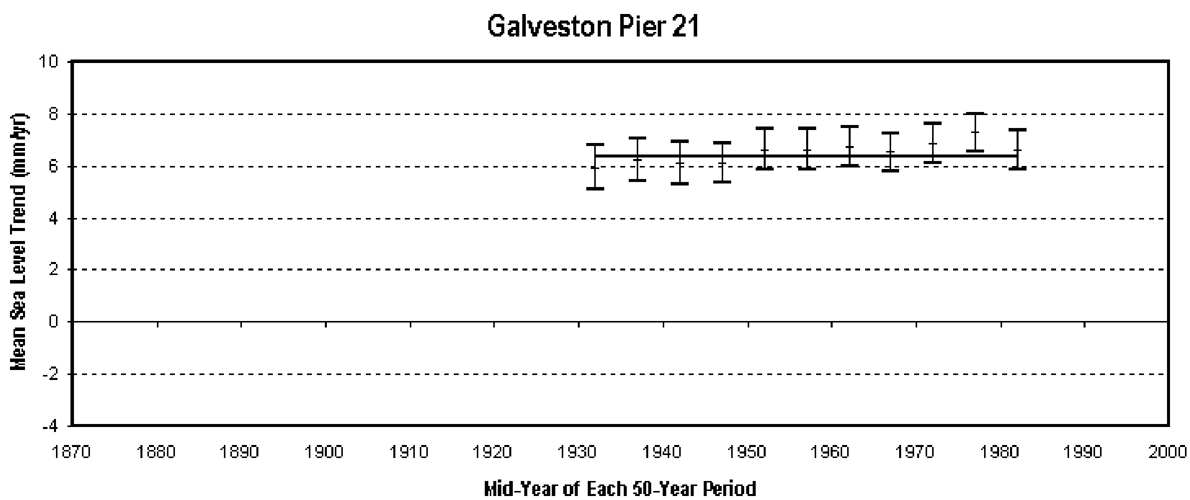

Charleston
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

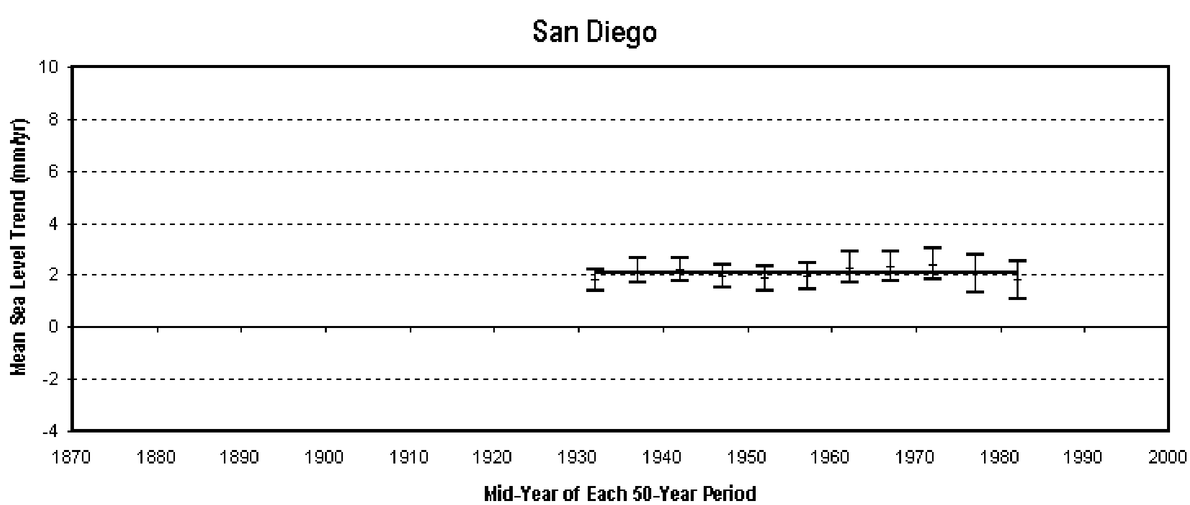

Fernandina Beach
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

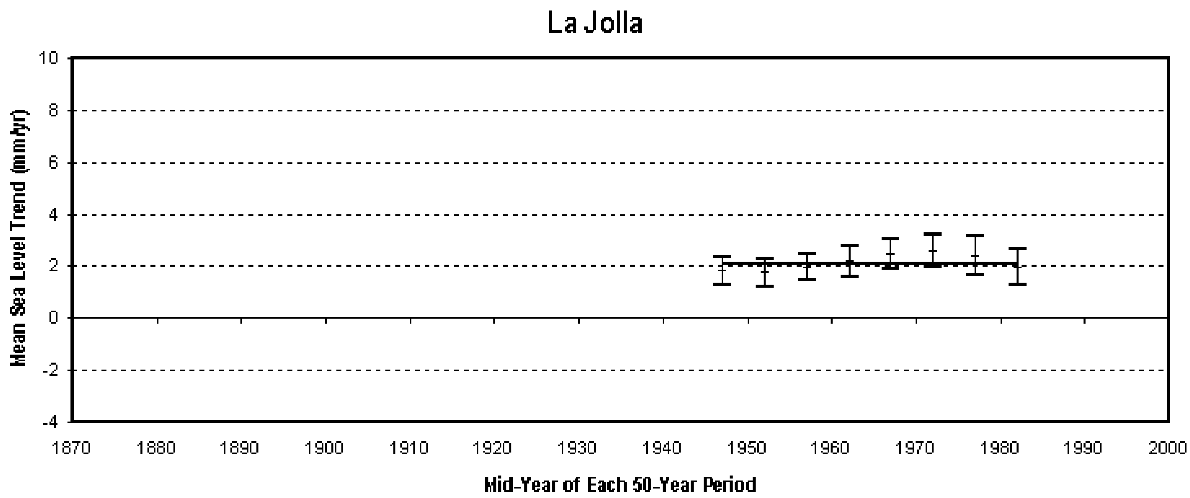

Key West
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

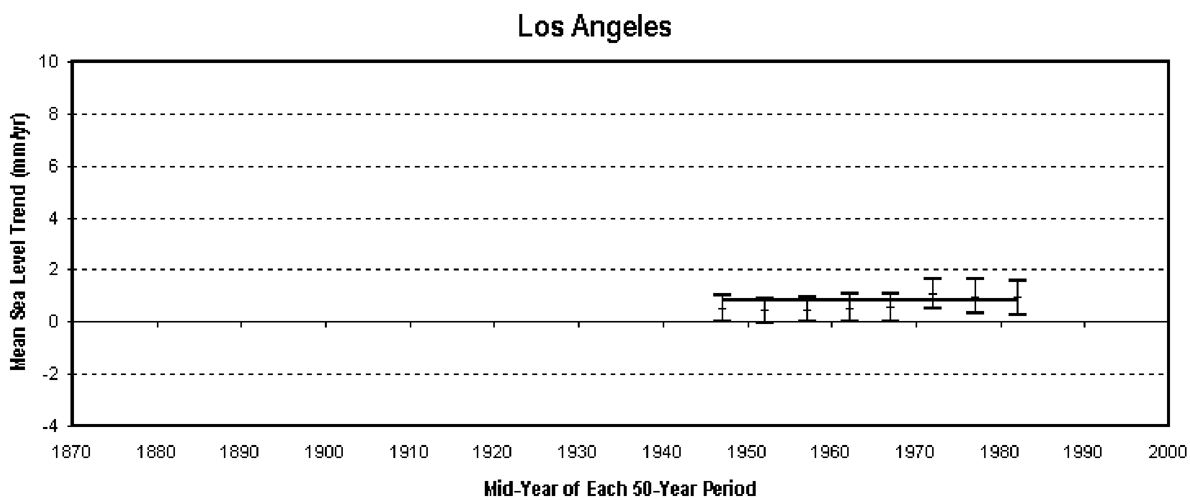

Cedar Key
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

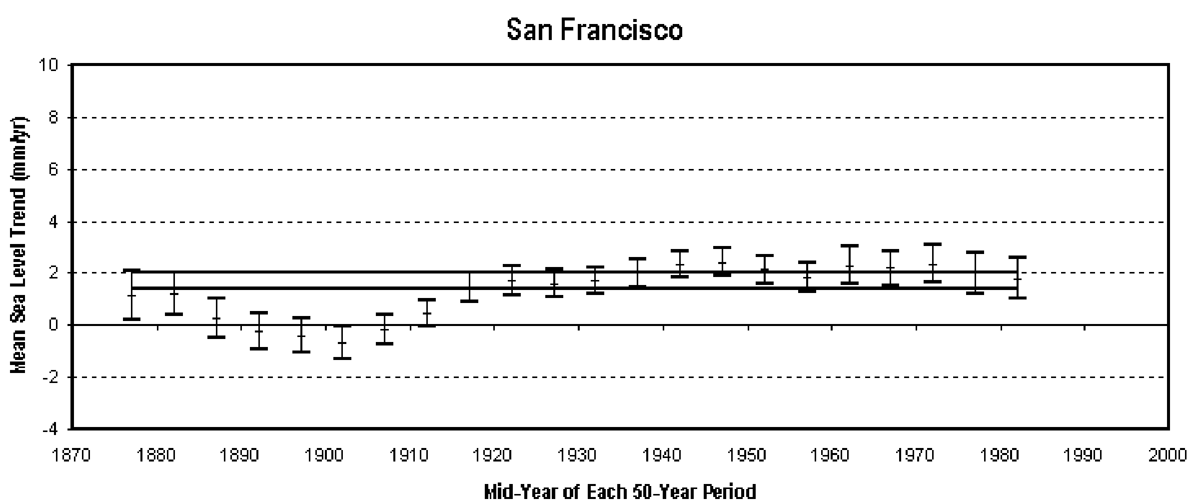

Pensacola
10
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

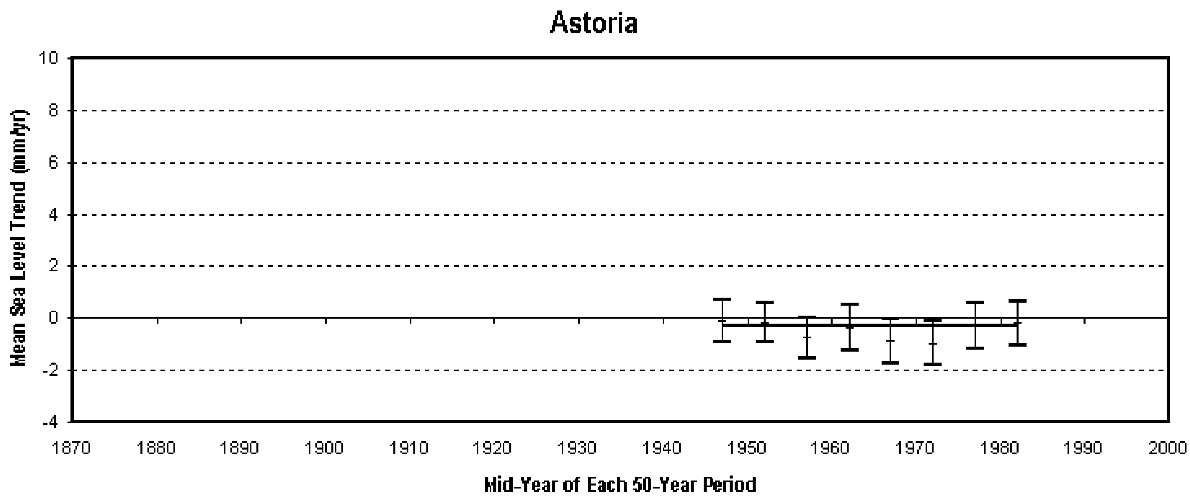

Galveston Pier 21
10
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

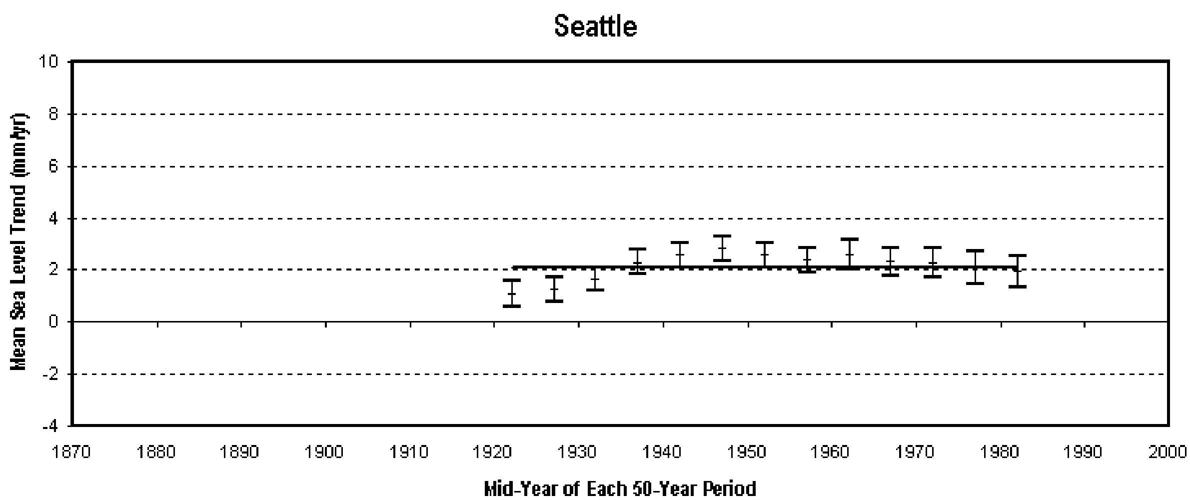

San Diego
10
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

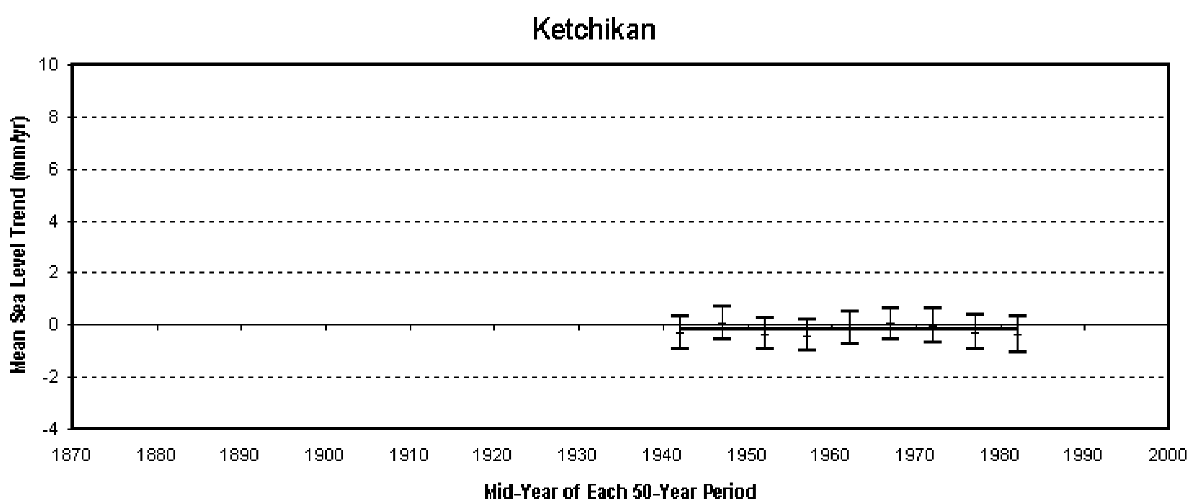

La Jolla
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

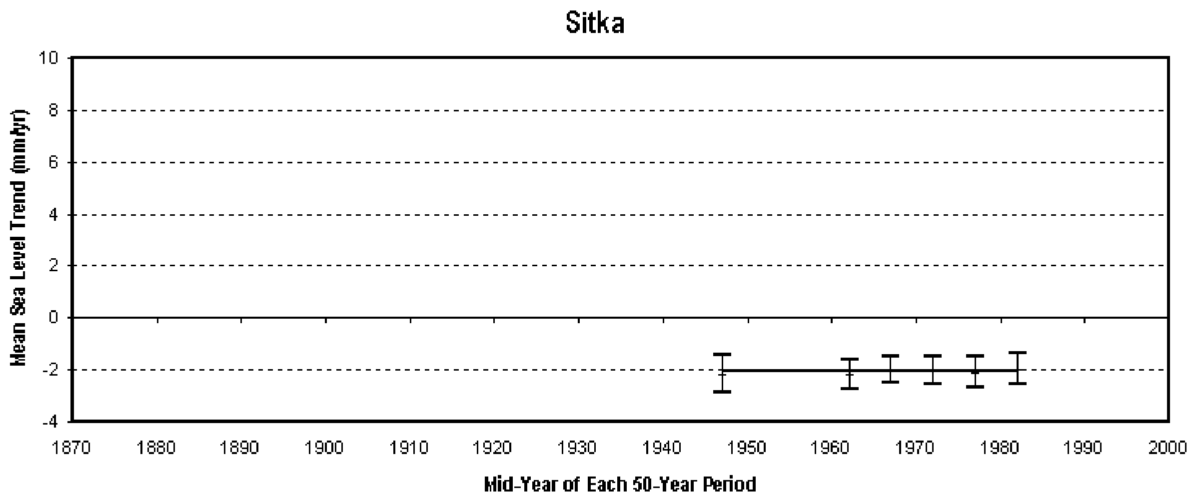

Los Angeles
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


San Francisco
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Astoria
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Seattle
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Ketchikan
Mean Sea Level Trend (mm/yr)
10
8
6
4
2
0
-2
-4
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period


Sitka
10
8
6
4
2
0
-2
-4
Mean Sea Level Trend (mm/yr)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mid-Year of Each 50-Year Period

http://www.tidesandcurrents.noaa.gov/